MAIZE
FOR BETTER NUTRITION

SG2000/IAR/FMARD

Editors: S. Miko, J.A. Valencia and A.M. Falaki

PROCEEDINGS

of National Quality Protein Maize Production Workshop
4th to 5th September, 2001

Institute for Agricultural Research Conference Hall
Ahmadu Bello University
Zaria

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Organized by: Sasakawa Global 2000 Nigeria Project,
IAR/ABU and FMARD

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AAA	Amino Acid Analyzer
ABU	Ahmadu Bello University, Zaria
ADPs	Agricultural Development Projects
AKIS	Agricultural Knowledge and Information System
BNF	Biological Nitrogen Fixation
BV	Biological Value
CBN	Central Bank of Nigeria
CIMMYT	Centro International De Mejoramiento De Maiz Y Trigo. Int.
CRI	Crop Research Institute
DNA	Deoxyribo Nucleic Acid
EAs	Extension Agents
ELISA	Enzyme-linked Immuno-Sorbent Assey
EOs	Extension Officers
EPZ	Export Processing Zone
FAO	Food and Agriculture Organization
FASCOM	Farmers Supply Company
FCT	Federal Capital Territory
FDA	Federal Department of Agriculture
FGN	Federal Government of Nigeria
FMA&RD	Federal Ministry of Agriculture and Rural and Rural Development
FOB	Free on Board
FPR	Farmer Participatory Research
FSR	Farming Systems Research
GCA	General Combining Ability
GLS	Grey Leaf Spot
GOs	Government Organizations
IAR	Institute for Agricultural Research
IAR&T	Institute of Agricultural Research and Training
IITA	International Institute for Tropical Agriculture
ICRISAT	International Crop Research Institute for Semi-Arid Tropics
KADP	Kaduna Agricultural Development Project

KASCO	Kano Agricultural Supply Company
MAS	Markers Assisted Selection
MSV	Maize Streak Virus
MT	Metric Tonne
MTP	Management Training Plot
NAERLS	National Agricultural Extension and Research Liaison Services
NAFPP	National Accelerated Food Production Programme
NARIs	National Agricultural Research Institute
NARs	National Agricultural Research System
NCRP	Nationally Coordinated Research Project
NGOs	Non-Governmental Organizations
NGS	Northern Guinea Savannah
NPU	Net Profit Utilization
NRC	National Research Council
NSS	National Seed Service
OAU	Organization for African Unity
OLS	Ordinary Least Square
OPVs	Open Pollinated Varieties
PCU	Projects Coordinating Unit
PER	Protein Efficiency Ratio
QPM	Quality Protein Maize
RAAKS	Rapid Appraisal of Agricultural Knowledge Systems
REFILS	Research, Extension, Farmers Inputs Linkage Systems
SAA	Sasakawa Africa Association
SAFE	Sasakawa Africa Fund for Extension Education
SCA	Specific Combining Ability
SG2000	Sasakawa Global 2000
T&V	Training and Visit
TOT	Training of Trainers
UNICEF	United Nations International Children Educational Fund
USA	United States of America

FORWORD

The workshop on Maize for better Nutrition could not have taken place at a better time than now when majority of Nigerians are relying on maize as their major staple food crop. QPM with its high content of lysine and tryptophan, two essential amino acids that are only found in meat and egg is a special maize that has been accepted by farmers. The introduction, promotion and dissemination of QPM by SG2000 through the state ADPs are great strides in providing maize with better nutrition to the resource-poor rural families who cannot afford meat and/egg in their daily diet.

SG2000 Nigeria with the support from SAA has assisted IAR in acquiring new stock of QPM germplasm and also provided financial support to promote research and subsequent release of new QPM varieties. Already, IAR has released Sammaz 14 (equivalent to Ghana's Obatanpa) for dissemination to farmers. In Kaduna and Kano states, QPM villages (where only QPM is grown to avoid contamination) are springing up and QPM is fast substituting normal maize, sorghum and millet on the field and in the preparation of local recipes like tuwo, waina, dambu etc. QPM gruel (koko) is also becoming the main weaning diet for babies in many rural communities.

Special attention however, needs to be paid in improving the postharvest storage and processing of QPM in order to reduce losses and maintain its quality. Reduction in storage losses can be achieved by introducing simple but locally improved storage methods through the use of suitable and safe plant materials and the triple polythene bagging that proved effective and popular with farmers for storage of legume and cereal grains.

The rate at which QPM is getting acceptability will undoubtedly also bring up new challenges to extension in the country. These challenges will entail changes in terms of methodology, responsive training along the QPM value chain, extension effectiveness and accountability.

For QPM promotion to fully succeed in the country, research needs to address some challenges including availability of good quality seed, development and release of superior QPM (OPVs and hybrids: white and yellow) varieties, promotion of no-till to reduce drudgery, improve soil fertility and check soil erosion and postharvest technology (harvesting, cleaning and storage). If the needed research is undertaken to develop and disseminate better quality QPM, right quality and quantity of fertilizer is applied, no-till is effectively promoted among farmers, suitable postharvest technology is employed and reasonable price is assured at harvest time, Nigeria by virtue of its available cultivable land, good soil, adequate and well distributed rainfall, has the potential to produce the quantity of the QPM it requires and also have excess to export to other countries in the West African sub-region.

Dr Ahmed M. Falaki
Project Coordinator
SG2000 Nigeria

Sasakawa Global 2000 Agricultural Programme

The SG2000 programme is a partnership of two NGOs: Sasakawa Africa Association (SAA) whose President is Dr. Norman Borlang, and the Global 2000 programme of the Carter Center, whose chairman is Jimmy Carter. SAA is responsible for programme management; Global 2000's special brief is to engage, through President Jimmy Carter, in policy-related interventions.

The Nippon Foundation, formerly called the Japan Shiplpoulding Industry Foundation (JSIF), which was founded by late Ryoichi Sasakawa, provides the funding for the SG2000 Nigeria programme.

SG2000 Nigeria Programme works mainly with—and—through the ministries of Agriculture, primarily extension services, but also with NARIs and IARCs. Support for field demonstration/testing programmes of improved food crop technology with small scale farmers is the core activity, although over time we have added numerous new activities such as water harvesting, conservation tillage etc. The main programme objective is to accelerate the adoption by small scale farmers of modern food crop production technology (fertilizer, seed crop protection, chemicals and agronomic practices) in basic food crops mainly maize, wheat, sorghum, sesame, millet, cassava, rice and grain legumes.

The SG2000 project in Nigeria was established in 1992, initially operating in the northern state of Kano, (10^0 33' North, 7^0 34' East and 500m above sea level). The project was expanded the following year into the states of Kaduna, Jigawa and much later Katsina, Bauchi, Gombe, Zamfara, Sokoto and Kebbi. The project runs in close collaboration with the State Rural Authorities of KNARDA, JARDA, KADP, KTARDA, BSADP, GSADP, ZACAREP, SADP, Kebbi PCU, IAR, IITA, LCRI and ABU Zaria.

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Cover Picture

GENERAL REFLECTIONS ON THE WORKSHOP

Ernest W. Sprague*

It has been a pleasure attending this important workshop, organized jointly by the Institution for Agriculture, Ahmadu Bello University, The Federal Ministry of Agriculture and the Agricultural Development Project of each of ten States. I am particularly pleased that the theme was "Maize for Better Nutrition".

I congratulate you on following up the National Seminal Promotion of Quality Protein Maize that you held on December 19, 2000, with this comprehensive workshop that is concluding today.

The Formal Opening Section gave us an opportunity to learn that prominent people in Government support the work that is being done to develop and disseminate maize, which provides for better nutrition, like QPM, together with better production technology.

I hope this workshop is not an end in itself, because it addressed a number of issues that challenge all players to work together to greatly increase the production of Quality Protein Maize.

Dr. Agle mentioned that the health in Nigeria ranks a low 187 out 191 countries worldwide. Since health is greatly influenced by nutrition the message from Dr. Agle give us another compelling reason to greatly accelerate our combined effort in Nigeria, which is the number one maize producer and consumer in West Africa.

There are available, today, production technology and plant materials, including varieties and hybrid that together, are capable of greatly increasing maize production in Nigeria and much of West Africa, if seed and inputs were available.

I believe that the technology available in Nigeria is certainly capable of producing at least one million more tons of maize if fully utilized. To do this of course implies seed, fertilizer and markets are not major constraints

I would now like to summarize our concerns and prediction by looking at a few issues that I think imperative to the development of sustained agricultural production, in Nigeria and all other Nations.

Plant Materials

We cannot afford to be complacent. Research should set priorities. I would like to see a concentration on the continue development of superior QPM cultivars. There is every reason to believe that a dynamic maize

***Senior Consultant, Global 2000, The Carter Centre, Atlanta, USA**

breeding programme could quite quickly develop QPM cultivars with a yield potential 15 to 20 % greater than is available to the farmers.

Dr. Pixley mentioned the excellent tropical germplasm that is from CIMMYT. Although this germplasm, does not have adequate resistance to streak virus it would be extremely useful to Nigeria and West Africa. This germplasm should be obtained immediately and work begun to transfer streak resistance into it. This approach will be more faster, easier and less expensive that attempting to transfer quality protein into the germplasm that you now have.

In my view the effort to develop improved cultivars should be a combine regional and international effort involving the national programs in West Africa and the International Research Centers. The approach would greatly accelerate grains that could be made, unnecessary time consuming duplication.

Nutrition

We all know the nutritive value of QPM from studies that have been conducted in other countries. Ghana has taken the lead in studying the response of babies to QPM gruel. This work is important and I hope it will continue. The next step in this study is to add a small quantity of malt to the gruel, which causes it to turn to liquid. The liquid form of QPM gruel allows babies to substantially increase their intake of food. We should follow this work and be aware of the positive indicators that babies exhibit when weaned on QPM. The value of QPM for the physical development of children of all ages should be promoted in activities dealing with women groups.

Fertilizer

We know that maize responds very to soil fertility and other production technology such as weed control. I doubt, however that we know the most economical rate of nutrients to use in different soil types. We need to do research and produce response curves from which we could determine appropriate fertilizer rates based on cost of fertilizer and value of maize.

The high leached soils in West Africa are acidic to highly acidic, and the response to micronutrients should be studied. The fertilizer manufactures are adding micronutrients to bulk mixes. However I am not sure how well we understand the value of micronutrients and the role of soil acidity.

Research on response to plant nutrients should be conducted in the maize producing areas and not on experience stations where the soil will not be representative of the soil where maize is produced.

No-till

Dr. Findlay gave a very good presentation on no-till, which is popular with maize farmers in much of West Africa. It is an excellent technology that should be vigorously promoted. I think however that there is a need to study no-till with maize in various crop rotations.

In the discussion there was some concern expressed with regard to no-till. I believe that no-till has several advantages. It reduces the labour required to produce a crop, it helps to prevent soil erosion and it improves soil structure. I recommend that no-till be promoted and demonstrated by extension, and let the farmers decide on which technology works for them. They will only adopt technology that works and is productive.

There is also a concern that more vegetative material needs to be returned to the soil. No-till helps to satisfy this requirement.

Post Harvest Technology

All aspect of post harvest technology need to be examined and demonstrated. I think it is most important to look at the economic returns of post harvest technology at the farm level. We should follow the work that is being done in Ghana on post harvest storage and we should enlist the assistance of IITA and the SG2000 Post Harvest Technology Program.

Extension

Extension is vital to the adoption of beneficial changes and the extension service is doing a very good job with available technology. However, in my view extension should involve more field plot demonstrations. There is a need to assist farmers with storage, market prices etc. to perform their role better. The extension officers also need an opportunity to have a greater in depth knowledge of all production related issues.

Seed Production

Dr. Mc Cater gave an excellent presentation on seed Co-op activities and philosophy. Existing and potential seed producers should consider his message.

Availability of quality seed is a constraint to accelerated maize production in Nigeria and other west African countries. Unfortunately, to date, a seed industry has not developed. It is true that seed production has been encouraged, but an industry has not yet evolved. There has been a tendency for seed growers to rely on government agencies and NGOs to purchase the seed they produce. More positive effort needs to go into the development of a dynamic marketing and distribution system.

Seed production and marketing is a business of which growing and processing quality seed is only part of the responsibility. It requires business skills, marketing promotion and extension skills.

A further constraint, in my view, is the role that seed regulatory agencies and seed inspectors play. I know that the intension is to assure that no seed is sold that does not meet a prescribed standard, which is meant to protect farmers. However, with budget constraints, bureaucratic constraints and inadequately qualified staff this well intended function become a constraint, rather than a positive function to assist in the delivery of quality seed into dynamic seed market.

The marketing of inputs (fertilizer etc.) is, like seed, a business and must operate with good business management. Perhaps seed dealers or distributors that are well dispersed throughout the maize producing areas could also deal with fertilizers and other inputs.

Market

Maize farmers today are the mercy of greatly fluctuating prices. Because of laws of supply and demand, when more maize is available, the price is lower. At harvest therefore, when there is more maize available, farmers are forced to sell at a price that is too low. This greatly reduced the profitability of maize farming and is constraint to the use of the best-known technology.

Suitable intervention could stimulate a better price at harvest. On farm storage is a positive step, however many farmers are forced to sell immediately after harvest because they need money to pay their financial obligations.

A more stable pricing of maize is essential to stimulate more maize production. A planned government intervention that would take maize out of production areas at a reasonable price at harvest could make farming profitable. The maize taken out at harvest could be stored and later release into the market at suitable times, and at a reasonable price, to prevent maize prices from becoming too high. This would help stabilize maize prices throughout the year and would benefit the producer and the consumer.

The Honourable Minister mentioned that the Government would buy maize to prevent prices at harvest going too low. If the Government decide to intervene, there should be careful planning and execution of the program. An intervention program should not be on an ad hoc basis just in response to emergencies.

Potential

Nigeria has potential of becoming a major maize producing country. Average maize yields today are about 1.4 tons per hectare on 3.7 million hectares. As I mentioned, present technology could make it possible to produce an additional million tons on the same area. However this would be a small increase in average production per hectare.

Some participants in the workshop suggested that we must have hybrids to push average yields above 1.4 tons per hectare. I agree that good hybrids would be one option to accelerate production. However with the variety Obatanpa, yields of 5 tons per hectare are completely realistic.

Other factors are more important than the choice of hybrid or variety. It is the lack of good quality seed, appropriate fertilizer and weed control that has depressed yields. This will continue until these constraints or limitations are corrected and markets become available. The use of Obatanpa alone will not improve the average production of maize; likewise hybrids will not increase yield without the appropriate support technology.

If appropriate research is conducted to develop superior QPM hybrids, the most economical rate of fertilizer used is established, weed control is practiced and an appropriate market for harvest grain is developed, Nigeria could anticipate yields of 6 to 8 tons per hectare. All of these constraints need to be addressed.

It will be necessary to formulate appropriate policies on seed regulations. The private sector should be given the freedom to produce and market quality seed with minimum regulations. Also, initially, the Government may need to stimulate the development of volume will make the industry more profitable.

If all these were accomplished, in a very few years, Nigeria could be producing far more maize than is required of food and feed within the country. We need to anticipate this reality and think about other ways of profitably disposing of using maize. There should be steps taken to develop regional markets. The use of maize in feed especially, poultry, and for industrial needs such as starch and sweeteners should be considered.

If we ignore any one of the issues discussed we may, five years from now, see Nigeria's maize production at about where it is now. However, if all of the pieces are put together, I predict that Nigeria will soon be a major maize producer and an example to emulate in all of Africa.

OPENING ADDRESS:
Dr. Malami Buwai*

Your Excellency, The Governor of Kaduna State Alhaji Ahmed Makarfi;

Honourable Minister of Agriculture and Rural Development, Alhaji Adamu Bello;

Honourable Members of Kaduna State Executive Council;

Your Royal Highnesses;

The Vice Chancellor, Ahmadu Bello University Zaria, Professor Abdullahi Mahadi;

Director of Maize Programme CIMMYT, Mexico, Dr. Shivaji Pandey;

Director General, IITA Ibadan, Dr. Lukas Brader;

Distinguished Guests;

Ladies and Gentlemen,

Thanks for honouring me to chair the formal opening of this very important National Maize Workshop. The survival of our young democracy will depend largely on our efforts to feed our people. Maize crop is not only high yielding but provide excellent food for both human and animal consumption. Maize therefore, has a vital role to play in the food security of our Nation. Through excellent efforts of Sasakawa Global 2000 and other Government Agencies, maize production has increased significantly; many farmers in the Northern States have now incorporated maize production in their farming system. Research Institutes and Agricultural Development Projects (ADPs) should continue to provide our farmers with technical guidance, improved maize seeds and other inputs to help further increase maize production in the country.

Federal and State Government should provide adequate support to our Research Institutes and Extension Services. Workshops and educational tours should be arranged for farmers both within and outside the country. Government must create favourable conditions for farmers to produce and market maize at profitable prices. There is also need for the Government to encourage the use of maize in beef fattening, milk production and poultry through price support programme.

Thank you for your attention and May almighty Allah Bless You All-Amin.

***Former Minister of Agriculture and Rural Development Nigeria**

SPEECH OF SPECIAL GUEST OF HONOUR :
Alhaji Ahmed Mohammad Makarfi*

I am glad to be called upon to address this gathering on this important occasion of the National Workshop tagged, ***"Maize for Better Nutrition."*** I understand that the workshop is jointly organised by Sasakawa Global 2000 (a Non-Governmental Organization), the Institute for Agricultural Research (IAR), Zaria; Federal Ministry of Agriculture and Rural Development, Abuja and some States Agricultural Development Projects with Kaduna inclusive.

Considering the role played by Maize as a major staple food and cash crop in this country in general and Kaduna State in particular, I must commend the Organisers for choosing Kaduna State to be the venue of the workshop. The choice of Kaduna State to host this workshop as was done in previous years by no means an accident, considering the position it occupied in Maize production in Nigeria.

The Kaduna State Agricultural Development Project (KADP) in conjunction with Sasakawa Global 2000 (SG2000) has continued to intensify efforts with farmers to expand the area under Maize cultivation and yield per unit area in the State.

I have been adequately briefed on the very impressive achievements that have been recorded in the State since the beginning of this our collaboration with SG2000 in 1993; especially in terms of number of participating farmers, technology adoption, yield increases per farm size, provision of logistics, in terms of various types of mobility and training to the States' indigenous extension staff and farmers. I have also been briefed that two of our staff are among other Nigerians enjoying your Special Scholarship Programme (SAFE-Programme) to pursue MSc and PhD. Degrees at Ahmadu Bello University, Zaria.

By way of encouragement to our farmers, Kaduna State is embarking on "***Back-To Land Programme"*** which engages school leavers to partake in modern Agriculture. About 2,300 Youths are involved in the programme this year across the State. This is part of the poverty alleviation programme of this administration.

I am pleased to learn that Sasakawa Global 2000 has diversified its technology transfer drive into other crops like Sesame, Soybeans, Rice, Cowpea, Cassava and Castor. This will also assist the boosting in production of these crops.

I wish to call on the seed Companies, agrochemical Companies and fertilizer Companies who are also participating in this workshop and who also provide very important and critical inputs for maize production, to improve on the quality of their seeds and other imputes sold to farmer.

With the theme of this Workshop "MAIZE FOR BETTER NUTRITION", it is hoped that the discussions will critically proffer solutions to all the identified constraints facing Maize production and utilization in this Country with the aim of getting the best benefits from its cultivation.

I will want to appeal to other indigenous public-spirited individuals and organizations that are endowed with resources to emulate the example of Sasakawa Global 2000 and initiate similar programmes with the aim of improving the standard of living of our rural people.

Mr. Chairman, distinguished guests, let me also seize the opportunity to call on our farmers to learn from their colleagues that have participated in the Sasakawa Global 2000 / KADP activities. It is through this that the benefits derived will diffuse to all parts of the Country to ensure sustainability.

I wish you very useful deliberations.

Thank you.

***Executive GAovernor, Kaduna State, Nigeria.**

ADDRESS BY THE HONOURABLE MINISTER OF AGRICULTURE
Mallam Adamu Bello FCIB (Dan Iyan Adamawa)*

Your Excellency
Alhaji Ahmed Mohammed Makarfi
Executive Governor of Kaduna State,

Hon. Commissioner of Agriculture
Kaduna State
Engineer Bawa Magaji,

All Other Commissioners Present,

Permanent Secretary
Kaduna State Ministry of Agriculture, Kaduna,

Professor Abdullahi Mahadi
Vice Chancellor,, ABU, Zaria,

Director,
Institute for Agricultural Research
ABU, Zaria,

Chairman of Seminar
Dr. Malami Buwai
Former Minister of Agriculture,

Directors of Departments, Federal and States,

Distinguished Scientists from CIMMYT,
Mexico, Zimbabwe, Ghana
United Kingdom and IITA, Ibadan,

Our Esteemed Visitors from Sasakawa Global 2000,

Senior Officers, Sasakawa Nigeria Project,
Members of the Press,

Ladies and Gentlemen,

I feel greatly honoured to be invited as a Special Guest of Honour at the formal opening of this Sasakawa Global 2000 National Workshop on the theme "Maize for Better Nutrition" with emphasis on High Quality Protein Maize (QPM).

First of all, I will like to join Governor of Kaduna State, Alhaji Ahmed Mohammed Makarfi and our Chief host, the Vice Chancellor of Ahmadu Bello University, Professor Abdullahi Mahadi, in welcoming our august scientists from Mexico, United Kingdom and sub-Sahara African countries, that have been invited to participate in this workshop. I have been privileged to interact with some of you and the SG2000 Country Directors in the Sub-Sahara Africa last Thursday, August 30th at the just concluded Field Day Tour of Maize MTP in some project sites in Kaduna and Kano States.

I will like to add that the theme for this workshop is most appropriate, because as most of you are aware, maize is one of the most important staple food crops in Nigeria. Over the years, Maize production has spread from the forest zone in the Southern Nigeria to the savannah regions of central/northern Nigeria. It occupied the unique position of the "hungry breaker" being the first crop to be at the disposal of consumers after the dry season. In that condition, maize is mainly consumed fresh as "Corn on the corb", boiled or roasted. In human nutrition in Nigeria, Maize is mainly processed into pap, dried and processed into flour pastes, mixed with legumes or fortified with other additives for rich baby foods. In milled form, maize is used to produce flour, bran, grit as well as starch. The grit is then used to produce breakfast cereals and baby foods.

Maize is a most useful source of livestock feed. It is infact the pivot of the livestock feed industry. The poultry industry in the country owes much of its past phenomenal growth to maize. While the nutrient composition of maize is said to be comparable to that sorghum (Guinea corn) and millet, maize has the added advantage of having ecological adaptability which makes it possible to produce it in virtually all over Nigeria. Because of the above uses of maize, as a very important staple food and poultry feed in Nigeria, my Ministry attaches great importance to boosting its production and its nutritional qualities, particularly the High Quality Protein content, which this workshop is focusing on.

Distinguished scientists and our august visitors, you may wish to recall that in the first week of July this year, former President Jimmy Carter of USA and his wife Roseline Carter visited the Sasakawa Global 200 plots at Kaduna where they were very pleased and satisfied with what they saw on the field; well tendered plots of maize and soybeans by the Gonin Gora Women Cooperative Society. The couple interacted with the farmers and advised them to source Quality Protein Maize seeds, which will help improve the nutrition of their families, especially the children.

Mr. Carter went further to advised the Vice President on the matter when my Ministry was directed to source QPM seed in Ghana SG2000 project where QPM work is advanced. We dispatched officers who reported of the wide adaptation of the crop and recommended the setting up of a Ministerial Committee on QPM.

The Inter Ministerial Committee had been inaugurated, had several times met and made recommendations to my Ministry for the coordinated national programme for the implementation of the High Quality Protein Maize in Nigeria so as to enhance nutritional status of the people. To accelerate the implementation of the programme, my Ministry has released One Million Naira each to IAR & OAU Ibadan and IAR/ABU, zaria for the installation of the Amino Acid Analyzer (AAA) already supplied to them. I will like to add that Ministry will give all the necessary logistic and financial support to the Committee so as to accelerate the introduction of the High

Quality Protein Maize seeds to the Nigerian Farmers.

The importance of the SG2000 Project to our Nigerian Agricultural Development efforts, is in no doubt particularly in the boosting of Maize production. It is a joy to note that the SG2000 Project in Nigeria, which started with a handful of farmers in Kaduna and Kano at inception in 1992, has spread rapidly to the neighbouring states of Katsina, Jigawa and Kebbi in the North West and to Bauchi and Gombe states in the North East. Equally, I am informed that farmers have rapidly embraced this Project strategy due to spectacular success it has recorded during its short life span since introduction. The crops grown also have broadened from the initial two crops of Wheat and Maize to include Rice, Soybean, Cowpea, Cotton Beniseed and Sorghum. Further, crop yields increased with consequent marked improvement in farmers income and well being. All these augur well for the food security of this nation and improved standard of living to our teaming farming families.

The successful implementation of the SG2000 programme in Nigeria on nationwide basis will no doubt contribute significantly to poverty alleviation. It is precisely for this reason that my Ministry had to seek extension of the SG2000 Agricultural Project for the next five years, to enable all the states of the Federation benefit from the project.

I am indeed, very delighted and the Country is very grateful that the request for the extension of project life was granted when Mr. Yohei Sasakawa, President of the NIPPON foundation of Japan, which is a co-sponsor of SG2000 Agric. Project, visited Nigeria in March last year to attend the SG2000 Wheat Field Day in Kano and Jigawa States. I' m pleased to inform you that my Ministry is making necessary arrangements to collaborate with Niger Republic to extend SG2000 Agric. Project to that Country.

Distinguished Ladies and Gentlemen, in conclusion, I am proud to be part of this seminar, which is aimed at the promotion of High Quality Protein Maize to improve the nutritional status of the Nation. With the presence of so many international acclaimed scientists at this workshop, there is no doubt in mind, that the outcome of this workshop will be of great benefit to Nigeria, particularly on the implementation of the High Quality Protein Maize programme in the country. It is now my singular honour, pleasure and privilege to declare this workshop open and wish you fruitful deliberations.

Thank you for your attention and God bless.

KEYNOTE ADDRESS: HONOURABLE MINISTER OF STATE FOR AGRICULTURE & RURAL DEVELOPMENT, CHIEF CHRIS AGBOBU

Our Chief Host
Professor Abdullahi Mahadi
Vice Chancellor
A.B.U.
Zaria.

Mr. Chairman
Eng. Bawa Magaji
Hon. Commissioner of Agriculture
Kaduna State

The Director
Institute for agricultural Research (IAR)
A.B.U. Zaria and
All other Directors

Our Esteemed Visitor from
(CIMMYT)
Dr. Ernie Sprague
Senior Consultant on Food Security

Senior Officers
Sasakawa Nigeria Project

Distinguished Scientists

Ladies and Gentlemen.

I am greatly delighted to be with you this morning on the occasion of this important seminar on the promotion of Quality Protein Maize (QPM) in Nigeria.

Perhaps it is in place to give a little background on this topic to show how greatly government attaches importance to this subject. In the first week of July this year, former President Jimmy Cater of USA and his wife Roseline Carter visited the Sasakawa Global 2000 plots at Kaduna where they were very pleased and satisfied with what they saw on the field; well tended plots of maize and soybeans by the Gonin Gora Women Cooperative Society. The couple interacted with the farmers and advised them to source seed of Quality Protein Maize, with the view to improving the nutrition of their families, especially the children

Mr. Carter went further to advise the Vice President on the matter. My ministry was directed to source QPM seeds from Ghana SG2000 Project where QPM work is advanced. We dispatched officers who reported of the wide adaptation of the crop and recommended the setting up of a Ministerial Committee on QPM. This, we did and the inaugural meeting of the committee was held in this very hall on Wednesday 30th August, 2000 and Chaired by today's plenary session Chairman, Mr. O.A. Edache, Federal Director of Agriculture, here with us in person.

Ladies and Gentlemen. It is with the above background in mind that I gladly accepted the invitation to come and deliver my opening address to this seminar, which is of such importance and significance to the work of my Ministry and indeed the food security of the nation.

The importance of the SG2000 Project to the Nigeria Agricultural Development efforts is immense. It is a joy to note that the SG2000 Project in Nigeria, which started with a handful of farmers in Kaduna and Kano at inception in 1992 has spread rapidly to the neighbouring states of Katsina, Jigawa and Kebbi in the North West and to Bauchi and Gombe States in the North East. Equally, I am informed that farmers have rapidly embraced this Project's strategy due to spectacular success it has recorded during its short life span since introduction. The crops grown also have broadened from the initial two crops of Wheat and Maize to include Rice, Soybean, Cowpea, Cotton, Beniseed and Sorghum. In addition crop yield at farmer's levels have doubled and in some cases nearly trebled the national average yields with consequent marked improvement in farmers income and well being. All these augur well for the food security of this nation and improved standard of living to our teaming farming families.

Ladies and Gentlemen, it is my singular honour and pleasure at this junction to extend to Mr. President, Chief Olusegun Obasanjo our immeasurable gratitude, for his singular efforts in introducing the Sasakawa Global 2000 (SG2000) Project to Nigeria, having visited on the invitation friend; former President Jimmy Cater to see what wonders the Project had done elsewhere in Africa and Asia.

This address will not be complete without touching on few areas of significance to my Ministry. As you know, Agriculture and Agricultural development are complex subjects with multifarious inter-related issues cutting across many disciplines; it is then outside the scope of the address to cover issues here. I will however, attend to the following few topics:-

Agricultural Research : My Ministry oversees the 18 Agricultural Research Institutes in the country and their affiliated Training Colleges. Research is the cutting edge for development whether in Agriculture or Industry; in public as well as in private development. All advances in Science and Corporate technology and new products are achieved through research and development. In the field of Agriculture, all the wonders of the High Yielding Varieties (HYV) of the 1970;s which have brought about the Green Revolution in Asia are the products of research by dedicated Scientists such as Noble Laureate Dr. Norman Bourlug, who we had the pleasure of having to grace our maize workshop in this very venue last year. In this regard, Government expects a lot from our research institutes facing the challenges of improving the farmers' productivity, through crop improvement and new production and processing technology development. As regards the Quality Protein Maize itself, I am made to understand that quality protein maize obtains in the country and all that needs to be done is to analyse them for the qualities of the requisite Amino-Acid (Lysine and tryptohan). The Ministry had already procured the analysers and allocated them to some research institutes, which need to install and operate them.

Farmers Organization: Organization is a key to any achievement at whatever level. The collective strength of our individual small scale farmers must be harnessed through viable Cooperatives.

Farmer operation expenses such as procurement of inputs (seeds, fertilizers, agro-chemicals, insecticides and herbicides) and farm power (tractors) increasingly getting out of the reach of the individual small scale farmers. On the part of the Government, my Ministry oversees the newly created Nigerian Agricultural & Rural Development Bank, which is funded to the tune of N1 billion to assist farmers in their operations. This clearly demonstrates on the part of the government, the political will and commitment to our farmers, who now need to organise themselves to make use of this government measures.

Private Sector Involvement in Agricultural Supply:

Agricultural input supply, as with any economic commodity, is by nature, a commercial and private sector activity. For the purpose of effective extension and the introduction of new technology, Government assists with subsidy and even assumes full responsibility of supply. However, when the technology is widely accepted and a ready market avails for it, then the private sector is expected to come in and play its commercial roles. This is what obtains in most developed agriculture, where the initial promotional role of Government has given way to private sector involvement in the fields of inputs supply, farm mechanization and even in aerial sprays for pest control. Here in Nigeria, we have giant commercial firms (UTC, UAC, the Lever Brothers just to mention a few), which have distribution outlets and warehouse facilities at the ports; who have the capacity and capabilities to import, warehouse, distribute and sell agricultural inputs just as any commodity as table salts or detergents. I am appealing strongly on behalf of government to our numerous firms to take the plunge and get involved in large scale Agricultural input Supply. The market exists and Government is willing to assist.

Distinguished Ladies and Gentlemen, in conclusion, I am proud to be part of your seminar, which aims at promotion of one of most promising vistas of improving the nutritional status of the nation: the promotion of Quality Protein Maize (QPM). Amongst you are eminent scientists who had dedicated their lives for such pursuit, who would undoubtedly guide your deliberations.

It is now my singular honour, pleasure and privilege to declare this seminar open and wish you God's guidance for fruitful deliberations.

Thank you for your attention and God bless.

MAIZE NO-TILLAGE SYSTEMS FOR REDUCED LABOUR REQUIREMENTS, IMPROVED SOIL CONDITIONS AND PRODUCTIVITY.

J.B.R. Findlay*

ABSRACT

For two to three thousand years, crop production has been based on soil inversion and cultivation to prepare a seedbed and to control weeds. This has led to a deterioration of soil structure and a depletion of soil nutrients resulting in poor yields and soil erosion. The concept of no-tillage for crop production is based on maintaining organic matter in and on the soil surface to improve the soil texture for a seedbed and using herbicides for weed control.

Reduced and no-tillage systems have been widely adopted by large-scale commercial farmers in many areas of the world, which has resulted in improved soil and moisture conditions, more reliable yields and improved profitability. This technology has been introduced to small-scale rural farmers in Ethiopia, Ghana, Kenya, Malawi, Mozambique, South Africa, Tanzania, Uganda and Zimbabwe in a co-operative partnership between Sasakawa Global 2000, Monsanto Company, government research and extension services and agricultural input suppliers.

Results achieved by farmers participating in these programmes are very encouraging in that time is saved and utilised more effectively, land preparation is easier, moisture utilisation is more efficient, crop production risk is reduced, yields are improved and profitability is greatly improved.

INTRODUCTION

Historical crop production systems have relied on the cultivation and inversion of the top soil layer to prepare a seedbed and to control weeds. This concept of bare soil technology by manual and mechanical means has resulted in a gradual deterioration of soil structure resulting in a pulverised soil which is prone to erosion, has depleted nutrient levels and often has a compaction layer on and below the soil surface which restricts water penetration into the soil profile as well as limiting the growth of the crop root system. In the rural communities of Africa, there is often a shortage of mechanical or animal traction and many hours of hand labour are spent in clearing land and preparing it for planting crops, which are grown primarily for survival with the production of a surplus as a secondary consideration.

The concept of reduced and no tillage systems is based on building up the organic matter layer on the soil surface with crop and other organic residues to form a mulch as well as to keep the crop root and stalks intact in the soil. The only cultivation done is a rip to break up any compaction layers present in the soil profile. There is absolutely no soil inversion, which can destroy the soil structure. The mulch on the soil surface allows for rain penetration into the soil without the possibility of soil surface compaction and crusting, it prevents moisture evaporation from the soil, it acts as a barrier to prevent physical erosion of soil by wind and water and it contributes to the improvement of the soil structure. The crop stalks and roots in the soil profile deteriorate and decompose, adding organic matter to the soil. The root canals allow for the aeration of the soil, but also create a system whereby water can rapidly enter the soil and be stored and also allow for the penetration of fertiliser to become distributed through the soil profile. The delicate roots of a new crop can penetrate this soil considerably easier than in a soil that has been pulverised and compacted as in conventional tillage. The concept is to turn crop production soils into compost on a scale that is considerably larger than the common home garden vegetable growing patch and the target is to get earthworms present in these large-scale crop production lands.

A major issue with this crop production system is that a suitable environment is developed for crop production but weeds are often the first to benefit from it. It is essential that an effective weed control programme based on herbicides and all other weed control techniques be implemented. Apart from herbicides, the mulch will suppress weed development, correct plant spacing will give a canopy that will shade out the weeds, the prevention of weeds being able to flower and produce seed will reduce future weed pressure and regular hand pulling or hoeing of weed escapes will all contribute to a reduction of weed pressure over time. Weed control must be seen as a twelve-month a year activity. Even during fallow periods, weeds must not be allowed to develop and exhaust the soil reservoir of moisture and nutrients. Weeds on headlands must also be prevented from flowering and seeding.

In many areas of Africa this technology has not been made available to rural communities for various reasons. The normal small-holder practice is based on a fallow rotation and 'slash and burn' technology. Programmes have been launched to make these small-scale farmers aware of no-till technology, which is widely implemented by many large-scale commercial farmers. This has been a partnership between Monsanto Company, Sasakawa Global 2000, government research and extension services and agricultural input suppliers. With the skills and resources required, no single organisation can successfully introduce new technology to small-scale rural farmers.

Considering that only 11% or 1500 million ha of the world's soil conditions are suitable for crop production (6% is permafrost, 10% is too wet, 22% is too shallow, 23% has chemical problems and 28% is too dry), there is an urgency for crop production to increase and become more efficient. Africa feeds 2.5 people per cultivated ha, South Asia feeds 9.5 and the USA feeds close to 11 people per cultivated ha (FAO). Clearly, the majority of the farming practices of Africa need to change and governments need to regard this as a priority.

Materials and Methods

The introduction of no-till systems is based on the training of field extension officers (EOs) and some of the progressive farmers in their area of responsibility and getting them to do a demonstration plot on each of the participating farmer's land together. In the first year of introduction, each EO should have between five and ten co-operating farmers, each with a no-till demonstration plot to compare with their normal production method in an adjacent field. These plots should preferably be within walking distance of each other to allow farmers to visit and discuss each other's results. There is an adjustment period for farmers and some EOs to accept a no-till concept, which is considerably different from the ploughing and soil inversion that has been promoted for many years. Due to this, it is advisable to support the no-till introductory group for two or three years to ensure the concept is being practiced correctly and to encourage commercial adoption.

The recommendation is for each demonstration plot to be 1,000 square metres (0.1ha) as this is an easy size to manage and calibration of seed, fertiliser and pesticide applications is simple. For the first two years and possibly a third, inputs for the establishment of a maize crop are donated to the farmer. This is normally 2.5kg certified seed, 10.0kg of a NPK fertiliser to be applied at planting and 10.0kg urea /ha to be applied as a top-dressing, 300 – 500ml of Roundup® foliar herbicide (contains 360g glyphosate /*l*, SL) for a pre-plant treatment and Lasso®+Atrazine residual pre-emerge herbicide (contains 350g alachlor and 200g atrazine /*l*, SC) for a post-plant pre-emerge treatment. In the initial stages, the EO and farmer establish and manage the demonstration plot together as it is a practical learning process for both. Keeping weeds under control is a major activity.

It is important that each plot has a data sheet for recording all relevant information and that it is completed in detail as each and every activity on the plot takes place. This is vital information to enable decisions to be made as to how to increase yields and whether all the recommendations are valid.

At the end of the season, it is important that the yield is measured. All the collected data are analysed, the cost of production is calculated and the profitability is then determined.

RESULTS

Time Saving

When fallow land is hand cleared and prepared for planting, as is done in most rural African areas, it will take one person the equivalent of up to 100 days labour to produce maize on one ha. This is very variable due to the types and densities of weeds and shrubs present. When a pre-plant Roundup spray is used to control the existing vegetation and using a no-till system, one person can produce maize on one ha in approximately 15 to 20 days (Soza *et al*, 1996). The total time spent in mixing and spraying each herbicide treatment is approximately 5 hours per ha, which accounts for 10 hours labour if a pre-plant Roundup application is made followed by a residual herbicide at planting. The planting, fertilising, weeding and harvesting account for the remaining time. Weeding in conventionally tilled lands is the major portion of labour required and often exceeds 60 days per ha for a good crop to be produced. These data collected during the programme in Ghana confirms the findings of Soza *et al* (1996).

By using the concept of a no-till system, a farmer can produce on 5 to 6 ha where only one ha could be prepared and planted under the traditional manual systems.

Weeding labour requirements in the crop were reduced to 10 days/ha with the use of residual herbicides in a no-till system compared to the traditional crop production reliance on hand weeding only from up to 60 days. In Africa, land preparation and weeding is done mostly by women and this time saving by using no-till allows more time for other activities.

In Zimbabwe, the Agricultural Research Trust farm near Harare reduced labour requirements by 46% when no-till was introduced. Over a 10-year period, labour requirements were reduced from 35 days/ha to 19 days/ha (Winkfield, 1995).

Cost of Labour

With more young people attending school and adult females entering alternative income generating activities, available manual labour in the majority of African rural areas is becoming more expensive with fewer people prepared to do this type of work. The farmers welcome the introduction of technology, which can alleviate this problem.

In Ethiopia, the cost of labour for weeding is US $ 1-25 to 2-50 per day. In Ghana this is higher at US $ 2-00 – 4-00 and in South Africa it can be as high as US $ 5-00 a day.

Farmers are looking for ways to reduce crop production costs and replacing hand weeding with herbicides is a very viable option.

Cost of Production

Generally, the cost of land preparation, planting, weeding and harvesting a maize crop grown with manual labour in the rural African communities is in the region of US $ 55-00 to 300-00 per ha. High weed pressure will necessitate an increase in labour costs. In some areas such as northern Ghana and Tanzania, use is made of mechanisation for land preparation, which results in an additional cost of approximately US $ 30-00 to 45-00 per ha.

The promotion of no-till maize based on herbicide use also includes the use of certified seed and fertiliser. This generally increases input costs by US $ 20-00 to 50-00 per ha but this is very variable due to labour required for weeding. On average, the cost of maize no-till production will range between US $ 70-00 and 200-00 per ha.

In northern Ghana, the 1999 no-till demonstration programme of the University of Development Studies suffered from severe drought (See * in Table 1). The average profit for 70 farmers was $ 21-81 but there were 25 no-till plots that made an average loss of $ 65-82/ha and 31 conventional plots that gave an average loss of $ 37-06/ha.

Table 1. *Examples of the cost and profit of maize production under conventional and no-till systems.*
(PP= Pre-plant herbicide; P+Pre= pre-plant + residual herbicide)

Location/Year/System	Yield (t/ha)	Cost ($/ha)	Profit ($/ha)	%
Ethiopia, 1998				
East Wolega (20 plots)				
Conventional	4.20	83-67	355-48	100
No-Till (P+Pre)	4.96	156-86	361-76	102
West Shoa (15 plots)				
Conventional	3.91	83-00	325-83	100
No-Till (P+Pre)	5.54	156-86	422-40	130
Ethiopia, 1999 (302 plots)				
Conventional	4.27	187-71	306-37	100
No-Till (P+Pre)	4.85	182-30	394-94	129
Ghana, 1997 (225 plots)				
Slash & Burn	2.5	66-67	211-11	100
No-Till (PP)	4.9	83-11	461-11	218
No-Till (P+Pre)	5.4	84-44	515-55	244
Ghana, CRI, 1999 (34 plots)				
Slash & Burn	2.81	53-57	227-22	100
No-Till (P+Pre)	4.97	70-00	426-70	188

Maize Yields

The no-till maize programme has resulted in increased yields due to the combination of certified seed (usually with over a 90% germination), high yielding hybrids and quality protein maize (QPM), NPK fertiliser and good weed control with herbicides. However, once farmers have been introduced to these technologies, they adopt some or all of them to a greater or lesser extent and this results in an increase in production.

No-till crop production is not aimed at producing record yields but rather at getting stable yields and improving productivity and profits. Due to time saving, land that would have been fallow can be brought into regular production. Apart from increased yields per surface area, a larger area can be used for production.

In Table 2, the comparison between the maize yield from no-till plots and the conventional farmers practice is given as well as the profitability (gross income minus the cost of production per ha) of the crop. The number of farmer plots that were monitored is also given. In Kenya there are data from the short rainfall season (s) and the long rainfall season (l) which also illustrate the effect of severe drought.

Table 2. *The average maize yield (t/ha) and the profit (US $/ha) under no-till and conventional till systems.*

Country & Year	No. Plots	No-Till Yield (t/ha)	No-Till Profit ($/ha)	Conventional Yield (t/ha)	Conventional Profit ($/ha)
Kenya					
1999 (s)	80	0.9	96-40 (+228%)	0	(-75+)
2000 (l)	250	0.9	96-40 (+383%)	0.1	(-34+)
2000 (s)	250	4.9	858-00 (+204%)	3.1	419-00
Tanzania					
1994	14	4.5		4.0	
1995	22	5.0		4.2	
1996	15	4.7	452-50*(+33.1%)	4.3	340-20*
1997	23	4.6	432-00 (+25.8%)	4.2	343-50
1998	125	4.4	445-00 (+10.5%)	3.8	402-80
1999	67	6.1	595-17 (+92.0%)	3.9	309-91
2000	15	3.5	334-19 (+50.6%)	2.9	221-88
[* average of 1994, 1995 and 1996 seasons]					
Ethiopia					
1999	302	4.9	394-94 (+29.0%)	4.3	306-37
1998 - 2000	701	4.2		3.8	
Uganda					
2000	735	5.0	214-00 (+38%)	4.6	154-00

Source: Findlay et al, 2001; Gebre *et al*, 2001.

In South Africa, a rural no-till project in KwaZulu-Natal was initiated in 1998 with 140 demonstration plots and this increased to 300 in 1999 and over 720 in 2000. The average maize yield under the traditional cultivation practice is up to 1.0 t/ha, whereas the no-till averages range between 2.3 and 7.7 t/ha with a maximum of 13.4 t/ha (Berry *et al*, 2001).

A similar project was initiated at Mlondozi, Mpumalanga, South Africa, in 1999 with 17 no-till maize plots giving an average yield of 2.9 t/ha compared to 1.3 t/ha for the conventional method (Berry *et al,* 2001).

When converting land from conventional to no-till, certain benefits are immediately apparent but it takes at least 3 years for the soils to start improving and give consistently reliable yields. Much of these data are from first year no-till plots and a considerable improvement can be expected when the system has been practiced for a number of years.

Profitability

Apart from increasing maize yields, the no-till system must be profitable for the farmers. It is important that a financial analysis is done on all demonstration plots. Apart from the food security aspect of improving agricultural production, it is also very important to create wealth in the rural communities of Africa. The major and quickest way to create this wealth is through farming and governments have a responsibility to support their farmers by paying a fair price for the produce and encouraging local production.

From Tables 1 and 2, it can be seen that the no-till maize production system being promoted does give a significant increase in profitability. As better cultivars are introduced and a better understanding of fertiliser requirements develops, no-till crops will become even more profitable.

Farmers must be prepared to establish their own markets. In Ghana, farmers that were previously considered as maize farmers have put all their grain into poultry production and become major exporters of poultry. Other Ghanaian farmers have concentrated on the production of green maize for fresh human consumption and developed a new market. Seed production is another option. The production of sweet corn is almost unknown in rural African communities and this can be a very viable product for export. By following this route, maize production can be more profitable than just producing grain.

Fertilization

The vast majority of cultivated soils in Africa are nutrient deficient due to a lack of fertiliser use and the continual burning of all organic matter every year, which prevents a build up of soil structure. There is also a lack of information and soil analytical support facilities. More often than not, it is due to the non-availability of any form of fertiliser and the expenses involved in getting it to the farming areas that limit the use of this commodity.

In Ethiopia, there is decided lack of nitrogen in the soils and recommendations were inclined to be conservative. A trial conducted at the Bako Research Station indicated that there was a positive response to fertiliser levels (See Table 3.).

The maize fertiliser recommendations in KwaZulu-Natal are between 100 and 200 kg N /ha with an average of 140 kg/ha with 60 kg P /ha and 40 to 115 kg K /ha. (Farina *et al*,

Table 3. *Maize yield response to recommended fertilizer levels at Bako Research Station, Ethiopia.*

Fertilizer Rate	- 25%	Recommended	+ 25%
No-Till	6.83 t/ha	7.86 t/ha	8.11 t/ha
Conventional	6.06	6.92	7.28

1993).

In Zambia, the standard fertiliser recommendation for no-till maize is 200 kg of N /ha or 200 kg urea /ha at planting followed by 100 kg urea /ha as a top-dressing at the 6 to 8 leaf stage of the crop (Aagaard, 1997). It is advisable to put on high rates of fertiliser in the first few years of converting to a no-till system in order to build up the nutrient levels in the soil. The organic matter on the soil surface will help prevent the degradation of nutrients.

Timing of Planning

The advantage of no-till crop production is that over a number of years, soil moisture will build up and allow for earlier planting, which enables farmers to plant long growing season and high yielding cultivars. Under no-till conditions, the plant available moisture was an average of 27% higher than under conventional tillage conditions (Berry *et al*, 1987), which contributes to earlier planting.

However, no-till does result in cooler soil conditions when compared to conventional bare soil tillage. The average soil temperature in no-till plantings was 19.6 ºC and 20.5 ºC for conventional tillage and this resulted in the time to 50% emergence being extended from 11 days to 13 days in no-till (Berry *et al*, 1987).

By conserving soil moisture using no-till, farmers will be able to plant during the optimum period. Farmers who wait for rains to plough will always plant late and get low yields. Ploughing and planting 18 days after the first planting rains will give a 25% yield loss and the crop will grow without 30% of the average rainfall (Aagaard, 1997). When well established, no-till will allow for better timing of planting as well as better planting conditions.

Disease Incidence

At certain times there is a suspicion that the incidence of maize diseases increase when no-till is adopted. Over a thirteen-year period, ear or cob rot (*Stenocarpella* spp.) was monitored on conventionally tilled lands and on no-till lands with no significant differences being recorded at an average infestation of 15.8% for no-till and 15.2% for conventional tillage. Similarly grey leaf spot (*Cercospora zeae-maydis*) (GLS) was monitored and there was no difference between tillage practices (Lawrence *et al*, 1999).

In order to reduce or eliminate disease incidence in maize, it is recommended to utilise a multi-facet system incorporating crop rotation, disease resistant or tolerant cultivars and fungicide sprays. No-till systems enhance crop vigour and improve the chances of survival. Low plant densities result in high GLS infections. The GLS spore infection is generally from crop residues and wind blown from other fields. Burning and / or ploughing crop residues into the soil do not reduce GLS infection.

CONCLUSION

By converting maize production from conventional tillage or 'slash & burn' to no-tillage, small scale farmers can benefit by saving time, increasing the area under production, increasing yields and producing a more profitable crop. There are numerous associated benefits such as better moisture utilisation, the prevention of soil erosion, improved soil structure and less labour requirements. Other crops such as soybeans, dry beans, cotton, sunflower and transplanted crops such as peppers, tomatoes, vegetables and tobacco can also be planted using the no-till system.

The technology required is relatively simple but the supply of the necessary inputs is essential and there is a cost associated with it. However, the increased profitability or economic benefit is well above the investment cost by uplifting maize production from a survival or food security issue to one where there is a surplus and additional income generated, and wealth created within the rural communities.

REFERENCES

Aagaard P J. 1997. Conservation farming handbook for small holders in region I & II. Published by the Zambia National Farmer's Union, Lusaka, Zambia.

Berry W A J, Mallet J B and Greenfield P L. 1987. Water storage, soil temperatures and maize (*Zea mays* L.) growth for various tillage practices**.** ***South African Journal of Plant and Soil*,** 4 (1), pp 26 – 30.

Berry W A J, Birch E B, Janse van Rensburg J, Fowler R M and Findlay J B R. 2001. A case study of conservation and no-tillage technology transfer – KwaZulu-Natal, South Africa. (In press) Paper to be presented at the 1st World Congress on Conservation Agriculture, Madrid, Spain. October 2001.

Farina M P W, Manson A D and Johnson M A. 1993. Maize in KwaZulu-Natal – Fertiliser guidelines. Natal Maize 6. Departmental brochure.

Findlay J B R, Modestus K W, Lawrence-Brown D, Miheso V and Matovu S. 2001. The introduction of conservation tillage practices to small-scale farmers in Kenya, Tanzania and Uganda. (In press) Paper to be presented at the 1st World Congress on Conservation Agriculture, Madrid, Spain. October 2001.

Food and Agriculture Organisation of the United Nations. Protect and produce – putting the pieces together. An undated FAO publication.

Gebre T, Retu B, Bekele K, Dubale P and Findlay J B R. 2001. The introduction of conservation tillage systems to small scale farmers in Ethiopia. (In press) Paper to be presented at the 1st World Congress on Conservation Agriculture, Madrid, Spain. October 2001.

Lawrence K F, Prinsloo M A and Berry W A J. 1999. Long and short term effects of tillage systems on grain yield, the incidence of diseases and production costs for maize. ***South African Journal of Plant and Soil***, 16 (2), pp 85 – 91.

Soza R F, Adu-Tutu K O, Boa-Amponsem K, Lampoh E K and Haag W L. 1996, revised edition. Soil conservation through no-tillage in Ghana. Paper presented at the 1994 annual meeting of the American Society of Agronomy, Seattle, Washington, USA, 13 – 18 November 1994.

Winkfield R. 1995. Conservation Farming. An unpublished paper presented at the Tinto Expo 95 congress at Harare, Zimbabwe.

BALANCED NUTRIENT MANAGEMENT FOR INTENSIFIED MAIZE-BASED SYSTEMS IN THE NORTHERN GUINEA SAVANNA OF WEST AFRICA.

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INTRODUCTION

In the past two decades, maize has spread rapidly into the savannas, replacing traditional cereal crops like sorghum and millet; particularly in areas with good access to fertilizer inputs and markets (CIMMYT, 1990). Maize production has expanded dramatically in the NGS of West Africa where it has replaced traditional cereals and serves as both a food and a cash crop. In West Africa, Manyong et al., (1996) assessed maize to be present as one of the five main crops of the farming systems in 124. 7 million ha. or 72% of the study area. The NGS alone took about 92% of total area grown to maize. Maize is also widely believed to have the greatest potential among food crops for attaining the technological breakthroughs that will improve food production in the region.

Market-driven systems are characteristic of a substantial part of the maize area in the sub-humid zones (36-43%) with the characteristic land use intensification (Mayong et. al, 1996). In Nigeria, for example, almost in everywhere, maize production has entered the intensification phase. However, continuous cultivation of the moist savannah zone with inadequate use of nutrient inputs in Nigeria has recently become a common practice as a result of a combination of rapidly expanding population and increasing urban market demand. This appears to be a microcosm of what the future seems to hold for the entire moist savannah zone in West Africa. This has however, occurred without the use of balanced nutrient management systems and thus the natural resource base of the soil is being continuously degraded. Soil fertility decline and particularly nutrient mining are widespread in sub-Saharan Africa, especially as agricultural populations increase. In consequence crop yields are falling to very low levels and poverty amongst agricultural communities is widespread. Declining yields, as a result of continuous cropping on exhausted soils, are seen to be a threat to food and livelihood security across the West African Savanna. For example, the reduction of fallow from 6 to 2 years has resulted in yield declines from 3 t ha^{-1} to about 0.7 t ha^{-1} for maize in certain areas such as the derived savanna of Benin (Houngnandan, 2000).

Nutrient requirements of Maize

One important characteristic of maize is its high and relatively rapid nutrient requirement. The soils for example, must supply about 50-60kg N (usually nitrate) and 30 kg P ha^{-1} in plant available forms for each ton of grain produced (Weber, 1996). Maize grain generally contains up to 2% N; that is, 100 kg of harvested grain contains 2 kg N (Carsky and Ewuafor, 1997). Total exports are 2.6 kg N per 100 kg of grain produced if aboveground residues are removed (Cretenet et al., 1994). Data by Violic (2000) show how quickly soil N can be depleted by maize (table 1) especially when yields are high and stover is exported. Even when yields are low on farmers' fields, soil nutrients are being mined beyond the power of the soil to replenish them.

Table 1 Nutrients removed from the soil by maize plant at different yield levels (Violic 2000

Part	Yield (t ha^{-1})	Nutrient (kgha^{-1})		
		N	P	K
Grain	1.0	25	6	15
Stover	1.5	15	3	18
TOTAL	2.5	40	9	33
Grain	4.0	63	12	30
Stover	4.0	37	6	38
TOTAL	8.0	100	18	68
Grain	7.0	128	20	37
Stover	7.0	72	14	93
TOTAL	14.0	200	34	130

Nitrogen is the most limiting nutrient in maize production in the humid and sub-humid tropics (Heuberger, 1998). Van der Pol (1991) estimated that average depletion of soil N by maize in south Mali was approximately 25 kg ha^{-1}. In contrast, phosphorus inputs and outputs were more or less in balance, thereby justifying an emphasis on nitrogen supply for maize.

In pursuance of the first paradigm of soil fertility management which is to overcome soil constraints to fit plant requirements through purchased inputs (Sanchez, 1994), chemical fertilizer use was widespread in the early 1970s for some crops in some countries. Manyong et al., (2000) for example, found the use of chemical fertilizers to be widespread in some farming communities in the NGS of Nigeria. In the study of two villages in the NGS of Nigeria, they found between 95-100% of farmers using fertilizers on their farms (Table 2). They attributed this widespread use of fertilizers to past agricultural policies where government had played a major role in the popularity of chemical fertilizers. Fertilizer subsidies (usually above 80%), good extension services, and the release of responsive and high yielding varieties promoted the utilization of chemical fertilizers (Smith et. al, 1997).

Table 2 Dynamics in maize and fertilizer adoption in northern Nigeria (Smith et al.,

	1970	1989
Maize as major food crop	33	96
Maize as major cash crop	0	70
Fertiliser introduced	33	100
Fertiliser Adopted	low	81

Several studies have highlighted the optimum levels of nutrient required for profitable maize production in Nigeria. Balasubramanian et al., (1978) conducted a series of response trials leading to a recommendation of 100 to 120 kg N ha^{-1} in the northern and southern Guinea savannas. Similar response was recorded by Chude et al., (1994) and Ajala et al, 2000 (Table 3) in the same zone. In addition to fertilizer rates, management is also an important factor in ensuring its efficient use.

Table 3 Weighted average grain yield of hybrids and open-pollinated varieties in several trials involving three rates of N application (Ajala *et. al.,* 2000).

Rate of N application	Hybrids	OP varieties	Yield difference	Standard error
120 kg/ha	4717	4083	634	135
60 kg/ha	4386	3028	1368	192
0 kg/ha	1813	1239	579	278

Splits application of N fertilizers to maize is usually recommended 1) if the N rate is high, 2) the maize is a late-maturing type or 3) leaching is likely because of sandy soils or high rainfall before maximum uptake rate by maize can occur. Where split application is recommended, the smaller part is applied around planting time and the larger part at 4-6 weeks after planting when maize is growing quickly.

Problems associated with the use of mineral fertilizers in maize

With the removal of subsidies and government withdrawal from the distribution systems in the mid 1980s, (Kwanashie et. al., 1997), coupled with the environmental degradation associated with continuous use of inorganic nutrients, fertilizer use dropped substantially. Average rates of fertilizer use in Nigeria are about 12 kg nutrients/ha of arable land and figures for other West African countries are lower (FAO, 1992). In addition to high cost, poor transportation and marketing infrastructure have often made fertilizer unavailable to the farmers. Manyong et al., (2000) found that irrespective of the popularity of fertilizer use in the NGS, 80% of the fields surveyed in two villages in the NGS received less than half of the 120 kg N/ha recommended for cereals in the study area. Thus fertilizer availability and cost are important factors affecting the use of inorganic fertilizers. Even if cheap fertilizers were to be widely available, their long-term heavy use will also aggravate the acidifying effects of these fertilizers. Ammonium sulfate for example acidifies the soil faster than other sources of N. It is well established that 1 kg of nitrate requires 1.75 kg of calcium carbonate for neutralization (Landon, 1991). However, lime is more inaccessible than nitrogen fertilizer in West and Central Africa.

Organic sources of N for maize

Because of the physico-chemical nature of savanna soils and the relatively high cost of inorganic fertilizers, another second paradigm (Sanchez, 1994), was enuciated: “overcome soil constraints by relying more on biological processes by adapting germplasm to adverse soil conditions, enhancing soil biological activity and optimizing nutrient cycling to minimize external inputs and maximise the efficiency of their use” The problem facing farmers is that their soils cannot supply the quantities of N required and levels of N decline rapidly once cropping commences. Depletion of organic matter is approximately 4% per year, resulting in dangerously low organic carbon levels after 15 to 20 years of cultivation (Sanginga et al., 2001). At levels below 0.5% carbon, the soil supplies less than 50 kg N ha^{-1} and this sufficient for only about 1 t ha^{-1} of maize grain at normal levels of N use efficiency (Carsky and Iwuafor, 1999). In most cases, prevailing levels of soil organic carbon are below 0.5% thereby making it urgent to incorporate sources of organic carbon. Of the plant nutrients, N is unique in that supply and replenishment of soil capital need not entail the direct application of external inputs, but rather atmospheric reserves may be exploited through biological nitrogen fixation (BNF). N can also be supplied to field crops through use of animal manure.

Biological Nitrogen Fixation (BNF) may be exploited through the cultivation of legumes and other symbiotic plants. The nodulated roots and aboveground crop residues, left after the seeds and other components crops have been harvested, represent valuable sources of N for the replenishment of soil organic Nitrogen. Many ways to increase N supply by judicious use of N fixing plants have been tried in West African farming systems. These include their inclusion in the cropping system, their use in mixed cropping, as green manure, as cover crops, in agroforestry, etc. The increased use of legumes offers the potential for a significant decrease in the need for fertilizer N and is therefore a key component of sustainable agricultural systems. However, some of the technologies involving herbaceous and woody legumes have not been readily adopted by farmers because of lack of direct benefits as perceived by farmers. The use of grain legumes represents the single great opportunity in the integration of legumes in the cereal production systems in the Guinea savannas of West Africa. The adoption of new genotypes of grain legumes by farmers is usually very high compared to the introduction of herbaceous and woody legumes because no additional cost is involved and existing cropping systems are not affected. Amongst the grain legumes used in the West African region, cowpea and groundnut are predominant and a lot of work has been published on their importance and contribution in diverse cropping systems (Weber, 1996). Estimates of the benefits of cowpea to soil N supply are 80 kg ha^{-1} when residues from two successive cowpea crops are left in the field (Horst and Hardter, 1994) and 60 kg ha^{-1} when residues from one cowpea crop were incorporated into the soil (Dakora et al., 1987). Soybean may contribute to the N needs of maize in West Africa. The production and utilization of soybean has expanded approximately ten-fold in Nigeria over the past 10 to 15 years (Sanginga 1998). It has risen as minor crop (2%) in 1986 to 25% of all crops grown in Kaya village in the northern Guinea savanna. Now it is the second most important crop after maize. The contribution of N by soybean to the cropping systems depends on the maturity group (Table 4). Generally late maturing cultivars with low Harvest Index contribute more N to the soil than the early maturing cultivars.

Table 4. Effect of previous crop on total soil N (g kg^{-1}) before maize planting in 1994 at 10 locations in the northern (1-5) and southern (6-10) Guinea savanna of Nigeria (Carsky et al., 1997).

	Previous crop		
Location	Maize	Early soybean	Medium soybean
1	0.60	0.60	0.63
2	0.63	0.70	0.76
3	0.52	0.59	0.58
4	0.54	0.66	0.58
5	0.41	0.45	0.45
NGS mean	0.54	0.60	0.60
6	0.65	0.71	0.67
7	0.55	0.55	0.57
8	0.67	0.64	0.73
9	0.50	0.52	0.53
10	0.72	0.70	0.77
SGS	0.62	0.62	0.65
Combined mean	0.578a	0.613ab	0.627b
SE (Previous crop main effect)		0.010	

Previous crop combined means in a row followed by the same letter are not significantly different at P<0.05.

Use of N-Efficient maize varieties

One other approach to reducing the impact of N deficiency on maize productions, may be to select cultivars which are superior in the utilization of available N, either due to enhanced uptake capacity or because of more efficient use of absorbed N in grain production (Laffitte and Edmeades, 1994). There are variations among maize cultivars in the uptake and mobilization of N from leaves and stems to grains as shown by Akintoye et. al., 1999) (Table 5). Cultivars have been identified that are less responsive to applied N and these sometimes perform better at low N than do N-responsive hybrids or cultivars. It is expected that varieties with high N-efficiency will require less inorganic N in order to produce appreciable yields. Also they will benefit more from N released from preceding legumes in a cropping cycle. Progress has been made at IITA in the development of N-efficient maize cultivars and efforts are still being made to further improve these cultivars. A maize hybrid Oba Super II has been shown to yield consistently over 3 t ha^{-1} at 30 kg N ha^{-1}. Also maize breeding lines Low-Pool C1, C2 and C3 have given consistently high yield at 30 kg N ha^{-1} (Fig 1.). However, the full potential of these varieties can only be attained at this N level by integrating these varieties in the legume-cereal production systems in the northern Guinea savanna.

Table 5. N-use, N-uptake and N-utilisation efficiency of single, double-cross and a synthetic variety of maize evaluated in three locations and four N-rates. Akintoye et al., (1999).

Genotype	N-use	N-uptake Efficiency	N-utilization
	G grain/g Nf*	G Nt/g Mf	g grain/g Nt
Single crossesSingle crosses	35.4	1.16	31.0
1368x5012(1)	38.6	1.28	31.5
1368x9071(2)	39.6	1.35	30.8
1368xKU1414SR(3)	35.3	1.11	31.0
5012x9071(4)	37.3	1.17	32.8
5012xKU1414SR(5)	36.9	1.16	31.1
9071xKU1414SR(6)			
Double crossesDouble crosses	39.8	1.24	31.7
	36.9	1.22	30.9
1x6	38.6	1.28	30.8
2x5	30.4	1.06	27.8
3x4	0.8	0.02	0.4
SyntheticSynthetic	Probability>F		
SE (0.05)	0.01	<0.01	<0.01
Contrasts	<0.01	<0.01	<0.01
Single vs. double	<0.01	<0.01	<0.01
Single vs. synthetic			
Double vs. synthetic			

Maize-Legume-based cropping systems in the northern Guinea savannas

Legume-cereal rotation can reduce the fertilizer requirement of the cereal crop. The newly developed grain legumes can produce between 3 and 6 t ha^{-1} of dry matter, 2-3 t ha^{-1} of marketable grain, and still allow a positive soil balance. Agronomic trials indicate that maize yields generally are higher when the crop is planted following grain legume crops than in continuous maize. Therefore integrating N-efficient maize cultivars into this system will further alleviate the problems of N nutrition in maize-based systems. However, the N benefits to the system depend on the maturity class of the grain legume species. Sanginga et al, (2001) and Carsky et al., (1997) have shown late maturing legume cultivars to contribute more N and increase maize yield in cereal systems than the early maturing ones (Tables 6).

Maize growing after soybean was shown to significantly yield higher (1.2 to 2.3 fold increase) than the maize growing after maize (Sanginga et al., 2001). At a fertiliser rate of 20 kg N ha^{-1}, maize yield following medium maturing soybean was 33% and 76% higher in the northern and southern Guinea savanna zones, respectively, (Table 6) than maize following maize. Average yield increase due to the previous early soybean was 16% in the northern and 32 % in the southern sites (Carsky et. al., 1997). It is therefore expected that, N efficient maize will benefit more from a legume rotation where the grain legume cultivar fixes and returns more

N to the soil. Grain yield of an N-efficient maize (Low N Pool C2) supplied with 45 Kg ha^{-1} of inorganic N after a late maturing soybean for example, was 38% higher than the yield from the control plot with maize following maize (Sanginga et al., 2001) after just one year of rotation. These technology options seem to hold the future for the Guinea savanna zone of of West Africa where maize and grain legumes are well adapted and where farmers appear ready to adopt these technologies.

CONCLUSION

Maize has spread rapidly in the NGS of Nigeria since the 1970s due to improved access to market, availability of improved seeds and fertilizer. Because of the high nutrient demand by maize, its production requires high inputs of fertilizer. However, because of cost, unavailability, and low levels of soil organic matter, alternative organic sources of nutrients particularly N need to be included in maize fertliliza-tion. The use of animal manure in compound fields, grain legume-N-efficient maize rotation, addition of lower doses of inorganic N are needed to ensure an efficient nutrient management in the maize-based cropping systems in the NGS.

REFERENCES

Ajala, S.O., A Menkir and J.G. Kling (2000). Fertility Requirement of Open-pollinated and Hybrid Maize Genotypes. in Proceedings of a workshop Sustainable Maize Production in Nigeria: The challenge in the coming Millennium. SG 2000/IAR/FMARD/ADPs.

Akintoye, H.A., J.G. Kling and E.O. Lucas (1999). N use efficiency of single, double and synthetic maize lines grown at 4 N levels in three ecological zones of West Africa. Field Crops research 60: 189-199.

Carsky, R.J., B. Oyewole and G. Tian (1999). Integrated soil management for the savanna zone of West Africa: legume rotation and fertilizer N. Nutrient cycling in Agroecosystems 55: 95-105.

Carsky R.J., R. Abaidoo, K. Dashiell and N. Sanginga (1997). Effect of soybean on subsequent maize grain yield in the Guinea savanna zone of West Africa. African Crop Science Journal, Vol. 5 No. 1, pp. 31-38.

Carsky R.J. and E.N.O. Iwuafor (1995). Contribution of soil fertility research and maintenance to improved maize production and productivity in sub-Saharan Africa. In Proceedings of Regional Maize Workshop, 29 May- 2 June, 1995, IITA, Cotonuo, Benin Republic.

Cretenet, M., D. Dureau, B. Traore, and D. Bello, (1994). Frtilite et fertilisation dans la region sud du Mali; du diagnostic au prognostic. Agriculture et Development 3:4-12.

Dakora, F.D, R.A., Abonyinga, Y. Mahama, and J. Apaseku, 1987. Assessment of N fixation in groundnut (Arachis hypozea L.) and cowpea (Vigna unguiculata L. Walp) and their relative N contribution to a succeeding crop in northern Ghana. MIRCEN Journal 3:389-399.

Heuberger, H., (1998). Nitrogen Efficiency in Tropical Maize. Indirect selection criteria with special emphasis on Morphological Root Characteristics. Verlag Ulrich E. Grauer, Stuttgart, Germany. Pp 11-14.

Horst, W.J., and R. Hardter (1994). Rotation of maize with cowpea improves yield and nutrient use of maize compared to maize monocropping in an Alfisol in the northern Guinea anna of Ghana. Plant and soil. 160:171-183.

Houngnadan, P. (2000). Efficiency of the use of organic and inorganic nutrients in maize-based cropping systems in Benin. Ph.D thesis, Universiteit Gent, Gent Belgium.

Jagtap, S.S., (1995). Changes in Annual, Seasonal and Monthly Rainfall in Nigeria During 1961-1990 and Consequences to Agriculture. Discovery and Innovation Vol. 7 (4): 311-426

1. Proceedings of a Sympossium, March 25-29, 1996, CIMMYT, EL Batan, Mexico, D.F.: CIMMYT

Kwanashie M., Garba A-G, Ajilima I., (1997). Policy modelling in agriculture: Testing the response of agriculture to adjustment policies in Nigeria. AERC Research Paper 57, African Economic Research Consortium, Nairobi, Kenya.

Laffitte, H.R., and Edmeades, G.O., (1994). Improvements of tolerance to low soil nitrogen in tropical maize. I Selection criteria. Field Crops Research 39:1-14

2. **Landon, J.R., (1991).** Booker Tropical Soil Manual: A handbook for soil survey and agricultural land evaluation in the tropics and subtropics. Longman Scientific, Essex, England.

Manyong, V.M., Makinde K.O., Sanginga N., Vanlauwe B., and Diels J. (2000) Fertiliser Use and Definition of farmer domains for impact-oriented research in the northern Guinea savanna. Nutrient Cycling in Agroecosystems, In Press.

Manyong, V.M., Smith J., Weber, G.K., Jagtap, S.S., and Oyewole B., (1996). Macro-chracterization of agricultural systems in West Africa: An overview. Resource and crop Management Research Monograph No. 21. International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria.

Moll, R.H., Kamprath E.J., and Jackson, W.A., (1982). Analysis and interpretation of factors which contribute to efficiency of nitrogen utilization. Agron. J. 74:562-564.

Rodriguez, M. (1986). Agronomies du mais. Pp B-1 to B-45 in SAFGRAD. Annual report for 1986. SAFGRAD/IITA, Ouagadougou, Burkina Faso.

Sanchez ,P.A., Izac, A-M.N., Valencia, I., and Pieri, C. (1996). Soil fertility replenishment in Africa: A concept note. In: Breth, S.A.(ed.). Achieving greater impact from research investments in Africa. Chitedz Research Station/ Bunda College. Lilongwe, Malawi Sasakawa Africa Association, Mexico City.

Sanchez, P.A., (1994). Tropical soil fertility research: Towards the second paradigm. Volume 1. Inaugural and State of the Art conferences. Transactions 15th world congress of soil science, 10-16 July, 1994, Acapulco, Mexico, pp 65-88.

Sanginga, N., Okogun, J.A., B., Vanlauwe, J. Diels and K. Dashiell, (2001). Nitrogen Contribution of Promiscuous Soybeans in Maize-based cropping systems. Submitted.

Smith, J., Weber, G.K., Manyong, V.M., and Fakorede, M.A.B., (1997): Fostering sustainable increases in maize productivity in Nigeria. In Byerlee, D. and Eicher, C.K (eds). Africa's emerging maize revolution. Lynne and Rienner Publishers, London, UK.

Van der Pol, F., (1991). L'epuisement des terres, une source de revenus pour les paysans au Mali-Sud. Pp 403-418 in Savanes d'Afrique, terres fertiles? Proceedings of an International meeting at Montpellier, 10-14 December, 1990. Ministere de la Cooperation et du Development (France), Paris.

4. **Violic, A.D. (2001).** Integrated crop Management. In. Tropical Maize, Improvement and Production. FAO plant production and protection series No. 28.

Weber, G.; Smith, J.; and Manyong, V.M., (1996). Systems Dynamics and the Definition of Research Domains for the Northern Guinea Savanna of West Africa. Agriculture, Ecosystems and Environment 57:133-148.

QUALITY PROTEIN MAIZE: OVERVIEW, BREEDING STRATEGY AND RECENT RESEARCH RESULTS FOR SOUTHERN AFRICA

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BACKGROUND AND INTRODUCTION

Maize (Zea mays L.) consumption is projected to increase by 50% globally, and by 93% in sub-Saharan Africa from 1995 to 2020 (IFPRI, 2000, as cited by Pingali and Pandey, 2001). While much of the global increase in use of maize is for animal feed, human consumption is increasing and accounts for about 70% of all maize consumption in sub-Saharan Africa (Aquino et al., 2001).

Although maize is primarily a provider of calories, supplying almost 20% of the world's food calories, it also provides about 15% of all food-crop protein (National Research Council, 1988). From a nutritional perspective, however, the protein of maize and of most cereals is deficient in the essential amino acids, lysine and tryptophan (Olson and Frey, 1987). Several high-lysine mutants of maize have been identified, and the opaque-2 mutant has been selected by most researchers as the most amenable for use in applied maize breeding programs (Bjarnason and Vasal, 1992). Opaque-2 maize had several agronomic problems, such as low yield, ear rot, and slow dry-down, that make it unviable as a crop.

Breeding efforts at CIMMYT during the late 1960's and throughout the 1970's used a two-pronged approach to utilize the opaque-2 gene (Bjarnason and Vasal, 1992). In the first step, several broad-based populations and composites were converted to opaque-2. The second and more laborious step was to select kernels with modifier genes that gave the endosperm a normal, or translucent appearance, without relinquishing the increased protein quality contributed by the opaque-2 gene. The resulting maize is known as 'Quality Protein Maize', or QPM. This work in developing QPM has recently earned CIMMYT scientists, Drs. Vasal and Villegas, the 2000 World Food Prize.

QPM has about twice the lysine and tryptophan content of normal maize. In addition, QPM has a much lower ratio of leucine to isoleucine than normal maize, which is considered beneficial for the production of niacin (Bjarnason and Vasal, 1992; National Research Council, 1988). Due to these characteristics, the biological value (BV) or the amount of nitrogen that is retained in the body, is about 80% for QPM, compared to 40-57% for normal maize and 86% for eggs (Bressani, 1992). Another commonly cited comparison is that protein of normal maize has about 40%, whereas QPM has 90% the BV of milk (National Research Council, 1988). Finally, it can also be calculated that the Net Protein Utilization (NPU), which is the product of digestibility and BV, is about 40% for normal maize and 65% for QPM. It is important to remember that normal and QPM contain, on average, equal protein content (generally 8-12%); it is the protein quality which differs between them.

Much controversy surrounds the real value of QPM for enhancing the nutritional status of humans. Part of the controversy is whether malnutrition is most often due to calorie or protein deficiency. There are nutritionists who argue that increased consumption of alternate crops or protein sources would be more practical and effective than introduction of QPM. There are many data indicating that, when maize is the only source of dietary protein, QPM is of tremendous advantage over normal maize (e.g. Bressani, 1992). Although nobody would recommend use of maize as the sole source of dietary protein, maize is a primary weaning food for babies and a staple food of the population in several African countries. Replacement of normal maize with QPM could benefit these people.

CURRENT CIMMYT QPM BREEDING ACTIVITIES IN SOUTHERN AFRICA

There is a wealth of QPM germplasm available from CIMMYT's breeding programs in Mexico. Much of this QPM is competitive in tropical environments with normal maize for yield and major agronomic characters. Almost all of it, however, is susceptible to maize streak virus (MSV), an important disease of maize in sub-Saharan Africa. Secondly, most of the CIMMYT QPM germplasm is of lowland tropical adaptation whereas the majority of maize in southern Africa is grown in midaltitude environments.

QPM research by CIMMYT in southern Africa has focused on testing inbreds, hybrids and open-pollinated varieties (OPVs) developed elsewhere (primarily at CIMMYT, Mexico). Using results of the first trials (1999), several hybrids and OPVs were selected or formed with the objectives of evaluating them regionally. Most of the hybrids were three-way crosses among lines that performed "reasonably" well in Zimbabwe. Twelve hybrids were three-way topcrosses, using one of three OPVs as male for one of several single-cross hybrids. The topcrosses were formed to obtain hybrids with streak virus (MSV) resistance, as the only available QPM with MSV resistance are OPVs. It was also known that topcross hybrids would be easier to produce than conventional three-way hybrids, and that inbreeding depression would be less for topcrosses than conventional hybrids, thus making topcrosses more suited to farming situations where grain is often saved for use as seed. One disadvantage of topcross relative to conventional hybrids is greater difficulty in ensuring purity of the hybrid (because off-types are harder to identify and rogue from an OPV than from an inbred male parent during seed production of the final three-way hybrid).

For lowland environments, the Ghanaian QPM OPV 'Obatanpa' was included in trials first in Mozambique, and later throughout the region. Obatanpa has moderate level of resistance to MSV, and has large cobs that are liked by many farmers. Obatanpa was recently released and will be marketed in Mozambique as 'Sussuma'. Another promising OPV is PL15Q-SR, which has moderate resistance to MSV, flinty grain and is early maturing.

Inbred line and hybrid development

After identifying the most promising QPM lines based on their per se performance, a two-pronged strategy has been applied to develop improved hybrids. The first approach uses QPM OPVs with moderate resistance to MSV as males for single-crosses among the best (MSV-susceptible) QPM lines. This strategy was expected to produce useful varieties in a very short period of time. The second strategy is to cross best QPM lines with elite lines from southern Africa. Although we do not propose to convert elite lines to QPM, we do expect to achieve two valuable products: 1) elite QPM lines will be converted to MSV resistant, and 2) new MSV-resistant QPM lines will be developed from the QPM by elite line crosses. It is crucial that we quickly develop QPM lines with MSV resistance; these lines are needed for hybrid formation and for use as sources or donors of QPM (opaque-2 and modifier genes) for further breeding projects.

A possible protocol for conversion of normal maize lines to QPM is outlined in Annex 1. Note that the protocol can be interrupted at several points (seasons) to develop new lines that are QPM and have any desired percentage contribution from the recurrent parent.

Diallel Among QPM Inbred Lines

Nine QPM inbred lines were selected in 1999 for further study primarily based on their good adaptation (per se) in Zimbabwe. One line, 'GQL5', was obtained from the Ghana National Maize Program. Three of the lines (CML181, CML182 and WWO1408) trace their origins to the breeding program of Prof. Hans Gevers, at Pietermaritzburg, South Africa. The remaining four lines are from CIMMYT's QPM program in Mexico. Hybrids resulting from diallel mating among the nine lines were evaluated in replicated experiments at eight locations during 2000.

A summary of general (GCA) and specific combining ability effects (SCA) from the diallel trials is presented in Table 1. Lines GQL5 and CML181 had the best GCA for grain yield. Results allowed prediction of promising three-way and double-cross hybrids (Table 2), many of which are being formed during winter 2001 and will be evaluated in yield trials during summer 2001/02.

Open-Pollinated Variety Development

Three open-pollinated varieties performed well in regional trials during recent years. Obatanpa and PL15Q-SR (pool 15 QPM streak resistant) have moderate resistance to MSV, whereas S91SIWQ (synthetic 1991, subtropical intermediate maturity white QPM) is well adapted to midaltitude areas, but susceptible to MSV. We discovered that both Obatanpa and S91SIWQ had lower protein quality than expected for QPM, so we have begun improving them for this trait. PL15Q-SR has good protein quality, but needed some improvement for MSV and resistance to other diseases, especially rust. Three unique strategies are being used to improve each of these OPVs.

1. Obatanpa: We planted 1700 F2 plants of Obatanpa, infested them with MSV-viruliferous leafhoppers, and self-pollinated plants healthy for MSV and other diseases (particularly grey leaf spot (*Cercospora zeae-maydis*; GLS) and rust (*Puccinia sorghi*)). Grain from the F3 ears was screened on the light table (see below) and we kept only kernels with score 2 or 3. For each selected cob, one set of selected kernels was planted with MSV infestation at our winter nursery and the second set was subjected to protein quality analysis by ELISA

method (see below). Full-sib crosses will be made among good plants from selected families (good endosperm modification, good protein quality and MSV resistant). The full-sib families will be grown in yield trials next summer and protein quality will be determined for each family. Only the best families will be recombined to form the improved version of Obatanpa in mid 2002.

2. S91SIWQ: About 300 half-sib families were planted at Harare and healthy, GLS-resistant plants were self-pollinated. For each cob, grain samples were selected for good endosperm modification and a sub-set of the selected kernels was analysed for protein quality. Remnant, well-modified kernels of the best families was planted and recombined twice to obtain the improved S91SIWQ which will be ready for yield trials in summer 2001/02.
3. PL15Q-SR: About 1000 F2 plants were infested with MSV at Harare and only the best plants were self-pollinated. Seeds were selected for kernel modification and well-modified kernels of each cob were planted ear-to-row and infested with MSV. Full-sib families were formed among good plants in the best rows. Seed of the full-sibs was analysed for protein quality and the full-sibs were assessed for grain yield and agronomic traits in two replicates at one site with artificial infestation for MSV. Well modified kernels of the best families, combining protein quality, good yield and disease resistance (including MSV) will be recombined to form the improved version of this OPV.

Although CIMMYT is not currently converting normal OPVs to QPM (because there is ample good QPM germplasm for breeding work), a possible protocol for converting a normal OPV to QPM is outlined in Annex 2.

TECHNOLOGIES FOR QPM BREEDING

Light Table

A simple box or table can be constructed for evaluating endosperm modification during QPM breeding work. The top of the box must be an acrylic or opaque glass, and a source of light, such as fluorescent tubes, must be inside the box. Segregating maize kernels will be spread on top of the acrylic surface, and with the lights switched on inside the box, a worker will be able to classify maize kernels according to the degree of endosperm modification. Experience has shown us that kernels with 10-30% opaque area will generally have good protein quality; hence, we select kernels of endosperm modification score 2 and 3 (1=100% modified, or normal appearance; 2 =25%; 3=50%; 4=75%; 5=100% opaque). Kernels of score 4 and 5 are very opaque and thus unacceptable, whereas kernels of score 1 are likely to be normal and thus not high-lysine (or QPM).

Visual selection for kernel modification is an essential step in QPM breeding, regardless of which method is used to select for protein quality (see below).

Protein quality analysis

Protein content and quality can be determined in a standard laboratory following procedures described by Villegas et al. (1984). Briefly, whole-grain samples must be finely ground, the resulting flour defatted, and concentrations of nitrogen and tryptophan can be colorimetrically determined for duplicate subsamples. Previous work has shown that the concentration of tryptophan and lysine are highly correlated, so CIMMYT generally evaluates only tryptophan content, which is easier and cheaper to assess than lysine. We use only kernels of uniform size (avoiding those from the ends of the ears) in forming grain samples for protein analyses. During breeding of QPM it is essential to monitor both protein content of grain (i.e. percent protein in grain) and protein quality (e.g. percent tryptophan in protein) because these traits are negatively correlated (Pixley and Bjarnason, 1993).

ELISA

Wallace et al. (1990) described a rapid method to quantify the α-zein protein fraction of maize using enzyme-linked immunosorbent assay (ELISA). This information is useful to differentiate normal from high-lysine (unmodified opaque-2 or QPM) maize because both opaque and QPM have about half the α-zein relative to normal maize. The ELISA technique can be used in a breeding program to evaluate whether a grain sample is homozygous for the opaque-2 gene. For example, an F1 cross of normal by QPM would be self-pollinated to obtain a segregating F2 population (S1 bulk). Individual S1 plants would be self-pollinated to obtain S2 ears, and about 25% would be expected to be homozygous for the o-2 gene (50% heterozygous and 25% would be homozygous O2 or normal). Grain samples from each S2 would be evaluated using ELISA, and remnant seed of only the homozygous 02 will be planted for further work.

Marker Assisted Selection (MAS)

It has recently become possible to use MAS to accelerate QPM breeding work. There are three markers available for this purpose (J.M. Ribaut, personal communication). One of the markers is dominant, and will identify any genotype that does not contain a recessive o2 allele. This means that the marker will identify normal and heterozygous genotypes, and the breeder can then assume that all other genotypes are the desired, homozygous recessive type (o2o2). The advantage of using MAS is that the breeder uses leaf tissue from seedlings to extract DNA and conduct the assay. Selection of the desired types can be completed prior to flowering, and only the desired plants will be pollinated. Disadvantages of using MAS include costs of the technology. CIMMYT has successfully used MAS in QPM breeding work but has not yet concluded whether it is more efficient than using conventional breeding methods.

RECENT QPM RESEARCH RESULTS IN SOUTHERN AFRICA

A southern and eastern Africa CIMMYT regional trial, 'QPM00', consisted of 22 experimental QPM hybrids and two local checks (selected by each grower). This trial was grown at 60 sites from which 39 have returned data (Table 3). The trials had two-row plots, and were grown in an alpha-lattice designs with two replications. The trials were researcher-managed and were grown primarily on research stations. Trial sites included one with Low-N fertility and one with severe, artificial MSV infestation.

Study of Table 1 reveals several outstanding hybrids, including some three-way topcrosses using Obatanpa as male (e.g. CML144/CML159//Obatanpa and CML182/CML175//Obatanpa). As expected, these hybrids had acceptable yield when challenged by MSV; their above-average performance under low-N and drought, however, was fortuitous. Other hybrids merit further evaluation in countries where they performed especially well (e.g. CML144/CML159//CML182 in Malawi, Tanzania, Uganda and Kenya).

It is encouraging to note that the best QPM hybrid out-yielded the best local check at 29 of the 39 sites and that, averaged across all 39 sites, the yield of the best QPM hybrid was 26% above the best local check (Figure 1).

On Farm QPM Evaluations

Unreplicated, large-plot (6-rows x 10 m) evaluations of QPM hybrids were grown at nearly 50 sites in Malawi, 35 in Uganda and 15 in Ethiopia (data for Ethiopia have been reported elsewhere). The plots were randomly arranged at each site to allow analysis of the data using a randomized complete block (RCBD) model in which each site constituted a replication.

Malawi

Most of the hybrids had grain yield within one standard error of the trial mean (Table 4). The topcross 'CML144/CML159//S91SIWQ' was best and the OPV, 'S91SIWQ', was worst entry in the trial, although few differences were statistically significant.

Considering all the available data (Tables 3, 4 and 5), the best QPM hybrids for further evaluations in Malawi are CML144/CML159//Obatanpa and CML175/CML176//Obatanpa. The hybrid CML144/CML159//CML176 can also be considered if MSV resistance is not considered essential; however, data from QPM00 at 39 sites suggests this hybrid is generally poor relative to the others. It is probably worth further testing CML144/CML159//CML182 and CML144/CML159//CML181 (Table 3). CML144/CML159//S91SIWQ should be reconsidered once the improved version is available (summer 2001/02). Finally, CML144/CML159//PL15Q can be considered if an earlier maturing option is desired.

Uganda

The best hybrid in Uganda was CML144/CML159//Obatanpa (Table 5). A single-cross hybrid also performed well, but there is doubt that single-cross hybrids are appropriate for Uganda because of weakness of the seed sector and the higher price of this type of seed relative to three-way hybrid seed.

Considering all the available data (Tables 3, 4 and 5), the best QPM hybrid for further evaluations in Uganda is CML144/CML159//Obatanpa. CML181/CML175//Obatanpa should also be considered. If MSV resistance is not required for Uganda, then CML144/CML159//CML182 and CML144/CML159//CML181 should also be considered. As for Malawi, CML144/CML159//S91SIWQ and CML144/CML159//PL15Q may be worth further testing.

Uganda QPM Open-Pollinated Varieties

An unreplicated, large-plot evaluation of six open-pollinated varieties (OPVs) was carried out at 15 sites in Uganda, from which 13 returned data (Table 6). Four of the OPVs were QPM, 'ZM521' is not QPM and has been selected for tolerance to drought and low soil N fertility, and the local check was 'Longe 1', an OPV (not QPM) commonly grown in Uganda. There were no significant differences for grain yield among the six OPVs, indicating that the QPM varieties were competitive with the local check, Longe 1.

CONCLUSION

There has been an increased interest in QPM, following the award of the 2000 World Food Prize to CIMMYT scientists for their work in developing QPM germplasm. Although most of the available QPM germplasm is adapted to lowland tropical environments and is susceptible to maize streak virus, work is underway to develop appropriate QPM cultivars for mid-altitude maize-growing areas of southern and eastern Africa. One year of regional evaluation (37 sites) of QPM hybrids indicated that several conventional and topcross three-way hybrids merit continued testing. Several of these promising QPM hybrids were included with best normal commercial and experimental hybrids in regional hybrid trials in 2001; results will permit direct comparison of QPM hybrids with the best normal (not QPM) hybrids. Also during 2001 we are increasing QPM breeding and seed production efforts in southern and eastern Africa to ensure that new and better materials are available for testing, and that previously-identified, most-promising hybrids and OPVs are available for on-farm verification trials.

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REFERENCES

Aquino, P., F. Carrion, R. Calvo and **D. Flores.** 2001. Selected maize statistics. *In*: Pingali, P.L. (ed.). 2001. CIMMYT 1999-2000 World Maize Facts and Trends. Meeting world maize needs: Technological opportunities and priorities for the public sector. Mexico, D.F.: CIMMYT.

Bjarnason, M. and S.K. Vasal. 1992. Breeding of Quality Protein Maize (QPM). *In*: J. Janick (ed.), Plant Breeding Reviews, Vol. 9. John Wiley & Sons, Inc., New York, USA.

Bressani, R. 1992. Nutritional value of high-lysine maize in humans. *In:* E.T. Mertz (ed.), Quality Protein Maize. American Association of Cereal Chemists, St. Paul, Minnesota, USA.

National Research Council (USA). 1988. Quality Protein Maize. National Academy Press. Washington, D.C., USA.

Olson, R.A. and **K.J. Frey** (eds.). 1987. Nutritional Quality of Cereal Grains: Genetic and Agronomic Improvement. Number 28 in the series Agronomy. American Society of Agronomy Publishers. Madison, WI, USA.

Pingali, P.L. and **S. Pandey.** 2001. Meeting world maize needs: Technological opportunities and priorities for the public sector. In: Pingali, P.L. (ed.). 2001. CIMMYT 1999-2000 World Maize Facts and Trends. Meeting world maize needs: Technological opportunities and priorities for the public sector. Mexico, D.F.: CIMMYT.

Pixley, K.V. and **M.S. Bjarnason.** 1993. Combining ability for yield and protein quality among modified-endosperm opaque-2 tropical maize inbreds. Crop Sci. 33:1229-1234.

Villegas, E., E. Ortega, and **R. Bauer**. 1984. Chemical methods used at CIMMYT for determining protein quality in cereal grains. CIMMYT, Mexico City, Mexico.

Wallace, J.C., M.A. Lopes, E. Paiva and **B.A. Larkins**. 1990. New methods for extraction and quantification of zeins reveal a high content of γ-zein in modified opaque-2 maize. Plant Physiol. 92: 191-196.

Table 1.

Summary of GCA (right column) and SCA (within table) effects for a 9-parent QPM diallel mating evaluated at 8 sites in 2000										
Parent Line	**175**	**176**	**E1**	**E2**	**WW**	**174**	**181**	**182**		**GCA**
GQL5	**G**	**P**	**P**	**P**	**B**	**B**	**B**	**B**		**B**
CML175		**P**	**W**	**W**	**G**	**W**	**G**	**B**		**P**
CML176			**P**	**P**	**B**	**B**	**B**	**G**		**G**
Exp. 1				**W**	**P**	**W**	**G**	**P**		**W**
Exp. 2					N.A.	**W**	N.A.	**W**		**W**
WWO1408						**G**	**W**	**W**		**G**
CML174							**G**	**G**		**G**
CML181								**P**		**B**
CML182										**A**
			Best	**Good**	**Average**	**Poor**	**Worst**			

Table 2.

Three-way and double-cross hybrids predicted to be outstanding by a diallel among 9 QPM inbred lines evaluated at 8 sites in 2000	
Three-way	**Double-cross**
GQL5/CML176//CML181	WW/CML181//CML175/CML176
GQL5/CML175//CML182	WW/CML181//GQL5/CML176
CML181/CML182//GQL5	CML181/CML182//GQL5/CML176
GQL5/CML176//WW	CML181/CML182//GQL5/CML175
WW/CML181//GQL5	WW/CML182//GQL5/CML176
WW/CML181//CML176	WW/CML182//GQL5/CML175
WW/CML182//GQL5	WW/CML182//CML175/CML176
CML175/CML176//CML181	CML181/CML182//CML175/CML176
CML181/CML182//CML176	
CML181/CML182//CML175	
GQL5/CML176//CML182	
GQL5/CML176//CML174	
GQL5/CML175//CML181	
WW/CML182//CML176	

Table 3

QPM hybrids evaluated across 37 sites in E & S Africa 1999/2000							
Name	**Across**			**Southern Africa**	**Eastern Africa**	**N-Stress**	**Drought**
	Rel GY	**Rank**		**Across**	**Across**	**Across**	**Across**
	%	Avg	Stdev	t/ha	t/ha	t/ha	t/ha
Hybrids with anthesis date 65 to 68 d							
CML182/CML175//S91SIWQ	109	11	7	5.94	5.67	1.98	3.49
CML181/CML175//S91SIWQ	105	11	5	5.69	5.83	1.90	3.13
CML182/CML175//Obatanpa	113	12	6	5.44	5.81	2.07	4.18
CML175/CML176//S91SIWQ	97	12	6	5.64	5.65	1.85	2.51
CML181/CML175//PL15QPM	105	12	6	5.53	5.36	2.14	3.19
CML182/CML175//PL15QPM	100	13	6	5.02	5.30	2.08	2.91
CML144/CML159//PL15QPM	88	16	5	5.04	4.90	1.74	2.44
CML175/CML176//PL15QPM	84	17	5	5.08	4.74	1.82	1.87
Maturity group average				5.42	5.41	1.95	2.97
Hybrids with anthesis date 68 to 72 d							
CML144/CML159//CML182	116	7	5	6.62	6.66	2.31	3.04
CML144/CML159//CML181	111	7	6	7.11	6.92	2.01	2.53
CML181/CML175//CML176	109	9	6	6.15	6.02	2.20	2.87
CML144/CML159//Obatanpa	110	9	5	6.17	6.38	1.91	3.09
CML181/CML175//Obatanpa	101	10	6	6.16	5.15	2.15	2.53
CML144/CML159//S91SIWQ	112	11	6	5.88	5.52	2.17	3.89
Local check 1	105	11	8	6.28	6.07	1.44	3.36
Local check 2	108	11	8	6.26	5.67	1.40	4.14
CML175/CML176//Obatanpa	107	12	6	5.66	5.69	1.82	3.53
CML175/CML176	96	13	6	5.71	5.59	1.65	2.48
CML182/CML175//CML176	69	22	4	3.64	3.55	1.43	2.04
Maturity group average				5.97	5.75	1.86	3.05
Hybrids with anthesis date 72 to 74 d							
CML142/CML176	96	11	8	5.74	6.04	1.75	2.35
CML144/CML159//CML176	96	13	6	5.58	5.41	1.96	2.38
QS7705	101	14	7	5.15	4.94	1.95	3.41
CML149/CML176	80	17	6	5.03	4.43	1.57	2.21
CML141/CML144//CML176	75	17	6	4.96	4.44	1.52	1.55
Maturity group average				5.29	5.05	1.75	2.38
Mean	**100**	**12**	**6**	**5.65**	**5.50**	**1.87**	**2.89**
LSD (0.05)				**0.45**	**0.61**	**0.37**	**0.81**
Min	**69**	**7**	**4**	**3.64**	**3.55**	**1.40**	**1.55**
Max	**116**	**22**	**8**	**7.11**	**6.92**	**2.31**	**4.18**

Table 4

Malawi QPM Hybrid on-farm trial 2000 (23 Sites)						
Pedigree			**Ears/ Plant**	**GLS**	**Grain Text**	**Phaeo maydis**
	t/ha	Rank	#	1-5	1-5	1-5
CML144/CML159//S91SIWQ	3.97	1	1.09	2.6	2.6	3.3
CML144xCML159//CML176	3.83	2	1.10	2.1	2.4	2.8
CML175/CML176//Obatanpa	3.82	3	1.08	2.5	2.9	3.9
CML144/CML159//Obatanpa	3.71	4	1.10	2.6	2.3	2.9
CML142/CML 176	3.69	5	1.14	2.0	2.3	4.4
CML175/CML176//PL15QPM	3.59	6	1.02	2.4	2.3	3.2
CML175/CML 176	3.57	7	1.05	1.8	3.4	5.2
CML144/CML159//PL15QPM	3.49	8	1.10	2.6	2.6	4.6
CML141xCML144//CML176	3.46	9	1.20	2.3	2.7	2.6
CML149/CML 176	3.39	10	1.17	2.6	3.6	4.7
S91SIWQ(1)	3.04	11	0.99	2.5	2.8	4.2

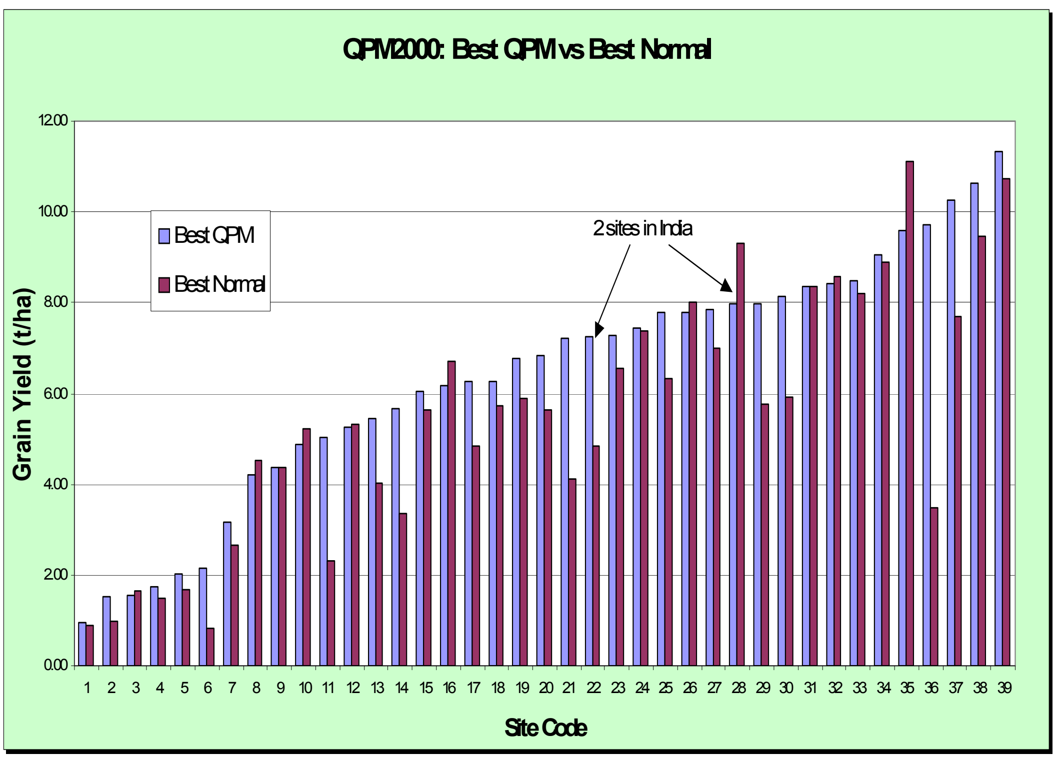
Table 5

Uganda QPM Hybrid on-farm trial 2000 (19 Sites)						
Pedigree			**Ears/ Plant**	**Husk Cover**	**E.turc**	**Farmer Rank**
	t/ha	Rank	#	1-5	1-5	
CML144/CML159//Obatanpa	4.96	1	1.04	1.8	1.9	1.0
CML142/CML 176	4.89	2	1.18	1.8	1.9	5.0
CML144/CML159//S91SIWQ	4.64	3	1.01	2.1	1.7	3.0
CML175/CML176//PL15QPM	4.42	4	1.04	2.3	2.0	4.0
CML144xCML159//CML176	4.40	5	1.06	2.0	1.8	7.0
CML144/CML159//PL15QPM	4.32	6	0.99	2.3	1.9	2.0
CML175/CML 176	4.20	7	1.04	2.0	2.2	8.0
CML175/CML176//Obatanpa	4.19	8	1.00	1.9	2.0	9.0
S91SIWQ(1)	4.06	9	1.02	2.1	2.2	11.0
CML141xCML144//CML176	4.00	10	1.19	1.9	1.8	6.0
CML149/CML 176	3.81	11	1.11	2.1	2.1	10.0

Table 6

Uganda QPM OPV on-farm trial 2000 (13 Sites)						
Pedigree	**Grain Yield**		**GLS**	**P.sorg**	**E.turc**	**Grain Text**
	t/ha	Rank	1-5	1-5	1-5	1-5
ZM521	4.86	1	1.8	1.3	2.2	2.9
LOCAL CHECK = Longe1	4.53	2	1.8	1.3	2.0	3.1
OBATANPA	4.48	3	1.9	1.7	2.4	3.0
PL15QPMc7-SR	4.36	4	2.1	1.0	2.1	2.8
[MID.ALT.QPM]C2	4.19	5	1.8	1.7	2.1	2.6
S91SIWQ	3.65	6	2.2	1.3	2.1	3.0

Figure 1. Comparison of grain yield of the highest-yielding QPM and normal check entry at each location of QPM00, a trial grown in eastern and southern Africa during 2000



Season	Objectives	Materials to Plant	Instructions
1	Form BC0F1	Plant 1 row of the recurrent parent and 1 row of each QPM donor line (Recommend using only 1 or 2 donor lines)	Make plant-to-plant (FS) crosses. Take pollen from one plant of the recurrent parent and pollinate one plant of the QPM donor line(s). Make 4-6 such pollinations for each donor line (s).
2	Form BC1F1	Plant 1 row of the BC0F1 formed in Season 1 and 1 row of the recurrent parent.	Make plant-to-plant (FS) crosses. Take pollen from one plant of the recurrent parent and pollinate one plant of the BC0F1. Make 4-6 such pollinations.
3	Form BC1F2	Plant 70 (to obtain 5 desired genotype) to 123 (to obtain 10 desired genotype) BC1F1 plants. Recommend planting 4-8 rows for each BC1F2.	Self-pollinate all reasonable plants. Note, if you anticipate making much selection, then increase the number of BC1F2 plants planted. Be sure to self at least 60 plants.
		Note: Efficiency can be increased by using markers to self pollinate only heterozygous BC1F2 plants.	If markers have been successfully used, then you only need to self-pollinate a minimum of 30 plants.
			Shell each ear of the BC1F2 individually. Evaluate the kernels of each ear on the light table. Keep only the ears with segregation for kernel modification (should be 12.5% (one-eighth), or 25% (if you used MAS) of the ears. Select only kernels with modification score of 2 or 3 for planting in season 4.
4	Form BC1F3	Plant the selected kernels from season 3. Keep separate plots for kernels from individual BC1F2 ears. Plant 2-6 rows from each cob (don't waste seed by double-planting for later thinning); more plants will allow more selection for agronomic traits.	Perform some selection for disease resistance and other agronomic traits and self-pollinate the best plants in each plot. If available, you can use the dominant marker to verify that plants are homozygous recessive for the o2 allele prior to pollination. Shell each ear individually and evaluate kernels on the light table. Keep only seed from ears segregating for modification. Keep all kernels with modification of 2 or 3. Use 10-20 of these selected kernels from each ear to perform protein content and quality analysis (ELISA or tryptophan content).

5	Form BC2F1	Plant ear-to-row, one row of selected (modification 2 or 3) kernels from each BC1F3 cob selected in season 4. Eliminate poor rows before flowering based on protein quality analysis. Plant also enough rows of the recurrent parent (normal inbred you are converting to QPM).	Make plant-to-plant (FS) pollinations using pollen from the recurrent parent for selected plants in selected rows of the BC1F3. Make 2-3 pollinations in each selected BC1F3 row. Note: You may wish to self-pollinate other good plants in selected BC1F3 rows and use these for line development.
6	Form BC2F2	Plant 6-10 rows of BC2F1 seed (more, if you would like to make strict individual plant selection for agronomic traits like disease resistance).	Self-pollinate all good plants. Shell each ear individually and evaluate the kernels of each ear on the light table. Keep only the ears with segregation for kernel modification (should be 25% of the ears). Select only kernels with modification score of 2 or 3 for planting in season 7.
7	Form BC2F3	Plant the selected kernels from season 6. Keep separate plots for kernels from individual BC2F2 ears. Adjust the number of rows to plant from each cob depending on how many cobs you kept from season 6; more plants will allow more selection for agronomic traits.	Self-pollinate good plants; by now these should resemble the recurrent parent. If available, you can use the dominant marker to verify that plants are homozygous recessive for the o2 allele prior to pollination. Shell each ear individually and evaluate kernels on the light table. Keep only seed from ears segregating for modification. Keep all kernels with modification of 2 or 3. Use 10-20 of these selected kernels from each ear to perform protein content and quality analysis (ELISA or tryptophan content).
OR 7, 8, 9	Form BC3F1	If you require an additional backcross, because you want to recover more of the genotype of the recurrent parent, repeat season 5 procedure during season 7	Repeat season 6, then season 7 formation of BC3F3.

Season	Objec-tives	Materials to Plant	Instructions
1	Form BC0F1	Plant 400-500 plants of the recurrent parent OPV	Make a bulk of pollen from at least 50 good (perform mild selection) plants of the recurrent parent OPV and pollinate 6-8 plants in each of the QPM donor lines. Break the tasels of plants used to make the pollen bulk to avoid using them again.
		Plant 30-50 plants of each QPM donor inbred line. Recommended to use 3-4 donor lines (minimum of 2).	Repeat above process at least on 2 additional dates. A total of at least 200 plants of the recurrent parent OPV should be included in the pollen bulks.
2	Form BC0F2	Plant 1000-1500 plants of the BC0F1 balanced bulk (formed using equal number of seeds from each BC0F1 cob harvested in Season 1). Recommended to keep separate balanced bulks for each donor line, but total planting will be 1000-1500 plants.	Select good plants for disease reaction and other agronomic traits. Self-pollinate the selected plants. Pollinate 500-800 plants. At harvest, select 400-600 best ears.
3	Form BC1F1	Plant ear-to-row (in half-rows, e.g. 2.5 m) the 400-600 BC0F2s produced in Season 2. Note: Each BC0F2 cob should be shelled individually and kernels should be screened on light tables; keep and plant only kernels with modification of 2 or 3 on 1 to 5 scale.	Identify with tags the best 4 plants in each agronomically acceptable row (NB: you may inoculate with some disease so as to eliminate worst rows). Leaf samples from these 4 plants of each row will be collected and sent for DNA extraction and molecular testing to identify o2o2, homozygous recessive plants.
		Plant 400-500 plants of the recurrent parent OPV	Make a bulk of pollen from at least 50 good (perform mild selection) plants of the recurrent parent OPV and pollinate MAS-selected plants in the BC0F2 lines. Break the tasels of plants used to make the pollen bulk to avoid using them again.
			Repeat the immediately-above step at least once.
			Pollinate a total of 300-400 MAS-selected plants. At harvest, select 200-300 best ears.

4	Form BC1F2	Plant 1000-1500 plants of the BC1F1 balanced bulk (formed using equal number of seeds from each BC1F1 cob harvested in Season 3)	Select good plants for disease reaction and other agronomic traits. Self-pollinate the selected plants. Pollinate 500-800 plants. At harvest, select 400-600 best ears.
5	Form BC2F1	Plant ear-to-row (in half-rows, e.g. 2.5 m) the 400-600 BC1F2s produced in Season 4. Note: Each BC1F2 should be shelled individually and kernels should be screened on light tables; keep only kernels with modification of 2 or 3 on 1 to 5 scale.	Identify with tags the best 4 plants in each agronomically acceptable row (NB: it would be ideal to inoculate with some disease so as to eliminate worst rows). Leaf samples from these 4 plants of each row will be collected and sent for DNA extraction and molecular testing to identify o2o2, homozygous recessive plants.
		Plant 400-500 plants of the recurrent parent OPV	Make a bulk of pollen from at least 50 good (perform mild selection) plants of the recurrent parent OPV and pollinate MAS-selected plants in the BC0F2 lines. Break the tasels of plants used to make the pollen bulk to avoid using them again.
			Repeat the immediately-above step at least once.
			Pollinate a total of 300-400 MAS-selected plants. At harvest, select 200-300 best ears.
6	Form BC2F2	Plant 1000-1500 plants of the BC2F1 balanced bulk (formed using equal number of seeds from each BC1F1 cob harvested in Season 5)	Form full-sib, plant-to-plant crosses, by taking pollen of one plant to pollinate one other plant. Use only good plants (perform mild selection), and use each plant as male only once (break tasel after use). Make at least 300 pollinations and keep 150-200 best FS ears at harvest.
7	Yield test and confirm quality	Plant a balanced bulk of the BC2F2 ears in yield trials	Compare yield and agronomic performance of the BC2F2 (new QPM version of the OPV) in trials including the original recurrent parent OPV.
			Send samples of the BC2F2 bulk for protein content and quality analysis.
		Recommended Option: Plant a yield trial at 3-5 sites with 169 or 196 FS entries (use the BC2F2 cobs harvested in Season 6). Be sure to keep at least 30 kernels - selected for good modification - as remnant seed for each entry.	Recommended Option: In addition to yield and agronomic traits, evaluate protein content and protein quality for each FS in the trial.

8	Increase seed and/or recombine selected families	If the new QPM OPV was competitive and looks useful per se; plant a seed production field using BC2F2 seed.	Seed production in isolation or by hand-pollination
		If the new QPM OPV has minor deficiencies, use the recommended option for Season 7 to improve it.	See Season 7
		If the new QPM OPV is inferior to the recurrent parent OPV, consider performing an additional back-cross.	See Seasons 5 & 6
		If you followed the recommended option during Season 7, use remnant seed to plant one row of each of the selected FS families (15-25 families).	Recombine the selected families.

TOWARDS DEVELOPMENT OF STABLE HIGH YIELDINGDISEASE AND STORAGE PEST RESISTANT QUALITY PROTEIN MAIZE

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INTRODUCTION

The four major uses of maize are livestock feed, human consumption, industrial purposes and seed. For the considerable part of the world's population, food supplies, proteins in particular are inadequate and insufficient. The global deficit in animal and vegetable protein supply can reach million of tons. Food supplies have not kept pace with the rising population. In many countries of the world national protein requirements from both animal and vegetable sources cannot be met because protein rich foods are especially scarce and costly. The supply of world population with more meat, milk. eggs and product of higher protein content can be enhanced through various means. One way is the improvement of content of the local staples. The other means is by improving the ratio of the fundamental amino acids (lysine and tryptophan) in protein (Balint, 1970). Global use of maize for direct human consumption has remained stable at 100 million tonnes per annum since 1988. Maize contributes 15 percent (more than 50 million tonnes) of protein and 19 percent of the calories derived from food crops in the world's diet (CIMMYT, 1999). Making animal products requires large amounts of foodstuffs. An increase in animal protein production necessitates adequate supplies of forage suitable both in quantity and composition. An increase in protein content and an improvement in protein composition are equally important in connection with the economic production of animal product and supply of better food for the consumers without changing food habits at a low price.

In a normal maize kernel, the endosperm protein is different from the embryo protein. About 80 percent of the protein content of the kernels is in the endosperm, while only 20 percent is the embryo. Among the endosperm, zein is quantitavely predominant and present about 50 percent of the total endosperm protein or about 40 percent of the total protein of the whole kernel. Being deficient in almost all essential amino acids with the expectation of phenylalnine and leucine, zein has a low biological value. There is an almost complete absence of lysine only insignificant amounts of tryptophan. The proteins of the embryo and the non-zein part of the endosperm have a higher biological value than zein does (Dumanovic and Denic, 1969). In contrast, the protein content in opaque-2 maize has a nutritic value of about 90 percent that of proteins found in skim milk—the standard against which cereal protein is normally measured (National Research Council, 1988). Adding the opaque-2 gene to the world's maize crop would add 10 million tons of quality protein to the world food supply. By 1986, Opaque-2

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maize was transformed into a maize that was 'normal' in all respect except for its superior nutritional value. Although the quality protein maize (QPM) has the same amount of protein as common maize, it has the usable proteins because the quality and biological value of QPM is about 90 percent that of milk protein. Beside the yellow kernel types of QPM may be unusually valuable in helping to overcome xerophthalmia, a vitamin A deficiency that is the primary cause of childhood blindness in many developing countries (National Research Council, 1988). Thus use of QPM will help reduce nutrition related diseases and deaths and significantly improve nutritional status of individuals who depend primarily on maize for sustenance (thialabein, 1969; Vasal, 1974; Ado, 1999).

Within the content of this workshop, development of QPM implies breeding of varieties that are better suited to meeting man's food needs. For this, the appropriate technology for control of diseases and pests have been included. The purpose of this paper is to present essential information needed to develop stable, high yielding disease and pest resistant QPM for Nigeria.

Breeding Objectives

To increase yielding capacity has been and still is the primary task of plant breeding. A basic requisite is that the experimental hybrids produced should approach the recommended hybrid in respect of yielding ability. The production of cultivars tolerant or resistant to field hazards such as diseases and pests is a perennial objective. Damage to maize due to bacteria, fungi and virus infection, insect infestation can sometimes be very important, hence they require great attention in order to reduce changes for economic losses. Today, the demand for quality is a worldwide phenomenon, accelerated by the application of agricultural chemistry. Thus, the breeding objective for improvement of nutritional value of protein in maize is concerned with increasing the deficient amino acids primarily lysine and tryptophan. Another basic breeding objective is to develop cultivars with broad adaptation to permit their production under a reasonable range of different environments. Improved cultivars must have high yield as well as stable performance. Early maturity is another objective especially, now that extra-early maize is cultivated in the Sudan savannah zone. Other objectives may include short plant height, good standability, striga resistance etc.

Inheritance of Quality Protein Traits

The inheritance of the characteristics chosen as breeding objectives will have a major influence on the strategy employed for cultivars development. Thus, in order to make progress it is necessary that breeding methods be selected in accordance with the principles of pure genetics. The genetic control of traits commonly include in breeding programs range from single major genes to complex inheritance (Fehr, 1987 and Hallauer, 1987). The characters, protein and oil content and each constituent amino acid, are hereditary traits. Frey (1949) reported that the protein content is determined by 22 genes.

Of these, only a few major but numerous modifier genes contribute to the formation of this character. Modifiers are genes that influence the expression of a non allelic gene or genes. They are minor genes that exert their influence chiefly by intensifying or diminishing the expression of the major genes, since their effects are weak. Since modifiers are inherited quantitatively, it is important to know how many modifier genes are involved and where these are located.

According to Nelson (1969), higher protein content is conditioned by genic systems. Floury-2 and Opaque-2 mutants both increase protein content. The floury-2 mutant is inherited as semi-dominant while the Opaque-2 is inherited as a simple Mendelian recessive with both the floury-2 and Opaque-2 being indistinguishable phenotypically. However, the floury-2 mutant tends to increase protein content largely by conditioning larger embryo size and increasing the content of non extractable protein. With regard to the effect of the Opaque-2 mutant, the difference in amino acid composition of the proteins is apparently confined to the endosperm. Thus, the substantial change that opaque-2 effects in the overall amino acid composition of the endosperm are not apparent when one examines protein taken from other tissues of plant. Dumanovic and Denic (1969) reported that a change in the content of one single amino acid may reflect a changed protein content, changed relative amount of protein fractions or change in the composition of the individual proteins. Samples with medium protein content exhibit the highest lysine production.

Frey (1949) ascertained that tryptophan level was controlled by 15 pairs of genes, zein by six, valine and leucine by eight and isoleucine by six pairs. Low tryptophan content is dominant. For breeding purposes, this implies that at least two high tryptophan lines are needed for the production of high tryptophan hybrids. High tryptophan contents are associated with favourable tryptophan percentage. This is understandable since an increase in protein content was associated with a doubling of the germ ratio, with a concomitant improvement in the tryptophan ratio. The amino acid composition is not dependent upon the protein content, even though if the proportion of zein increases with a rise in protein content, there is a depression of protein quality. The contradiction of the statement can be explained thus: if a marked increase occurs in the germ ratio the resulting quantitative rise in the germ protein may lead to an increased proportion of the amino acids. But a rise in protein content may occur without causing an increase in the germ ratio as a result of a rise in the endosperm level. Thus, it is better to increase tryptophan level in maize instead of increasing protein content. This is because there is negative correlation between increased protein per cent and yields. Increasing lysine per cent contributes remarkably to the better utilization of maize.

Development of Stable high yielding disease and Pest Resistant Quality Protein Maize

Different breeding procedures can be used effectively to develop superior cultivars. There are different factors that influence the choice of breeding procedure for the development of superior cultivars. The breeding methods and strategies developed for maize improvement have changed rapidly owing to the rediscovery of Mendelian genetics, development of experimental designs, analysis of variance and proper plot techniques and the pure-line method of breeding. Maize breeding is now more of a science than an act since the inbred-hybrid concepts are emphasized. For development of synthetic and hybrid cultivars, methods of determining the combining ability of an individual are of primary consideration.

Development of suitable QPM cultivars requires the contributions of the geneticists and plant breeders, crop protectionists, analytical chemists and biochemists, physicists and nutritionists. One very important point in choosing breeding techniques to improve quality protein in maize is the question of whether the amount of protein synthesized by a seed is conditioned by its own genotype of the plant on which it is borne. Anon. (1969), reported that in maize, the genotype of the plant itself seems to be far more important than the genotype of seed. In other words, the material parent determines the amount of protein with little influence of the pollen parent. Thus, selection for protein quantity should be based on plant basis rather than on seed basis.

Improvement of the chemical composition of maize by breeding is a difficult task. The length of time needed to develop a hybrid is usually 10-15 years. This period, however, varies among breeding programmes because of season available for breeding activities, source material used for extraction of lines, extent of testing and resources, available to increase lines and produce hybrids. With efficient use of growing seasons, the cycle time for development of new hybrids by the pedigree method of breeding may be only four to six years (Fehr, 1987).

Increasing size of germ is one of the approaches to develop high QPM because the embryo protein are of excellent nutritive value. Any change in size of the embryo in a positive direction will be reflected in increased contents of lysine and tryptophan. This approach will be very useful where whole grain is used for consumption. As much as 10.8 per cent of the total protein is located in the germ. Assuming a 10 per cent ratio, when the germ ratio is doubled, as much as 20 per cent of the proteins falls into the fraction with more desirable amino acid composition (Balint, 1970).

Germplasm Development

Success in the breeding of maize for higher quality requires first of all the corresponding genetic variability exists together with suitable method for detection and selection. There are basically two main sources of variability for inherited characters: those within the cultivated species and those found in the related wild species. They are an important source of genes for specific characteristics not available in commercial cultivars. Artificial mutagenesis by treatment with ionising radiation is one of the methods of creating useful genetic variability hitherto absent of natural germplasm. Gene mutations had markedly raised the level of the limiting amino acids in maize. Cell and tissue culture techniques may further expand the opportunities for the development and selection of genetic variability. Vasal (1974) reported that excellent opportunities exist for improvement in protein, lysine and tryptophan levels of Opaque-2 materials. Considerable variation for the traits had been observed and could be exploited within certain limits because of negative correlation between protein quality and content. Hallauer (1987) observed that maize breeders, presently, prefer genetically narrow-based populations including elite line synthetic with restricted genetic base, F2 populations of single crosses and back cross populations. Development and dissemination of maize germplasm that possess durable resistance to pests and diseases, tolerance to environmental stress as well as quality trait is one of the aspects of food security.

The Institute for Agricultural Research, Samaru has so far obtained QPM germplasm materials from the Crop Research Institute, Ghana and CIMMYT, Mexico. Additional germplasm materials were obtained from CIMMYT, Zimbabwe through the Sasakawa Global 2000. The germplasm materials have been planted for preliminary characterization. Materials with sufficient seed have been planted at Samaru, Funtua, Dutsin wai, Tiga and Kano. Visual vigor score indicates that some of the materials are promising.

Breeding Methods

Maize breeding involves the systematic improvement of the crop by controlling the percentage of the seed. Many breeding procedures have been suggested for developing new lines, modifying existing lines and improving germsplasm source for extraction of new lines. Two broad categories of breeding methods are used in maize improvement : developing of either new or modified inbred and population improvement to provide improved sources of germsplasm for development of new lines. Selection aimed at changing the chemical composition can also include a change in the morphological characters of the kernel and ears of the resulting varieties. Such selection may also reduce the grain yield. To avoid these undesirable effects, selection should proceed on the basis of those plants that are both high in protein percentage and protein quality per see

Pedigree selection is the most frequently used method for maize breeding and has been very effective in the genetic improvement of hybrid maize. Generally, the pedigree selection in maize is used to develop pure-lines that are used as parents of hybrids. Accurate records are essential to maintain the filial record (pedigree) of each genotype during each generation of inbreeding and selection (Hallauer, 1987).

Backcrossing is another obvious choice for line development. This method is usually used in context of transferring a trait from one genotype (donor parent) to an otherwise desirable genotype (recurrent parent). The trait been transferred is usually simply inherited. It is therefore a correctional breeding method that is used to enhance the performance of an elite inbred line, but it is also used to insert a specific gene in an elite inbred line. Alexander et al (1969) used F1 backcrossed to the current inbred parent. Heterozygotes segregate 3 normal: 1 Opaque. After five back crossings, Opaque-2 segregates were selected from the selfed ears. Thus, backcrossing is the easiest method for production of new lines. By this means Opaque-2 gene can be transferred to any ordinary line.

Population improvement can be achieved through current selection procedure. The steps for current selection include development of a heterozygous, heterogeneous population, selection among individuals within the population and intercrossing of the selection to form a new population. Vasal (1974) reported that intra population selection scheme of full-sib family selection have raised the yield level of some opaque-2 materials. For traits which are controlled by additive gene action, full-sib family selection would be very effective. Several circles of the current selection could be employed to create genetic families whose kernels have both high nutritional value and desirable agronomic characteristics. In each year, about 40 percent of superior families would be analysed and selected. In subsequent growing seasons, reciprocal crosses would be made between individual plants of these families. At harvest, 250 pairs of ears would be analysed and selected for the next cycle of evaluation.

The steps for development of inbred lines for use in the production hybrid cultivars include the development of a segregating population, inbreeding of the population to obtain homozygous individuals, evaluation of inbred lines for combining ability, evaluation of inbreds for use as parents in producing superior hybrids. Hybrids generally yield better and maintain their genetic quality more consistently. Thus, hybrids are a way of stabilising the purity of QPM traits. However, the draw back here is that the hybrid seeds have to be produced by seed companies and farmers must buy new seed each year, with its attendant high cost relative to open pollinating seed. The ultimate economic benefits are however innumerable. In Nigeria, hybrid seeds are used by progressive farmers who have the required capital to purchase seed and other inputs for intensive maize cultivation. Open pollinated and synthetic cultivars on the other hand are used mainly by subsisting farmers. Recent trends have shown that use of hybrid cultivars, however, are spreading rapidly even among resources poor farmers. For the farmers who utilize grains as seed, top cross QPM hybrids could be recommended, (Pixley, 2001). In the near future, use of biotechnology particularly cell and tissue culture may expand the opportunities for the development and selection of useful genetic variability in Nigeria maize breeding endeavour.

Diseases and Pests

Although the implications of developing resistance to maize diseases and insects, will only be mentioned briefly here, Vasal (1974) reported that four major limitations of Opaque -2 materials include greater vulnerability to ear rot pathogens and greater infestations by weevil, both in the filed and in storage. This may result from the floury endosperm of the Opaque-2 maize which fosters fungal growth (National Research Council, 1988). According to Ortega (1974) pathogens causing disease and insect pests are more prevalent and more severe at altitudes below 1,200 to 1,500m elevation in the tropical belt. Under these conditions, temperature and moisture and the prevalence of insect vectors, influence the severity of the pest complexes in time and space. Ortega (1974) further reported that temperature and moisture are the major agents regulating the geographical distribution of insect pest and pathogens. In the Nigerian context, four major disease and pest problems require intensive and systematic work. There are the maize streak virus (MSV), corn stunt and its associated insect vectors, the borer complex and the downy mildew complex. Although there are less well defined close associations of maize-maize-pathogen-insect relationship, maize ear and stalk rots caused by Fusarium can become more prevalent when earworm and stalk borer larvae are abundant. Such interrelations require the crop protectionists, the breeders and the agronomists to work together jointly to produce appropriate pest management practices to reduce pest damage. In the converted Opaque-2 materials, Fusarium ear rotting was significantly higher in tropical, subtropical and highland environments as compared to their normal counterparts. The incidence of ear rotting is associated with higher earworm susceptibility. Reaction to other foliar diseases and insect pests seems to be similar to that observed in 'normal' counterparts (Ortega, 1974).

The endemic presence of sorghum downy mildew (Sclerospora sorghi) and maize in West Africa, and its dispersal in several countries poses a serious threat to maize production. In Nigeria, the disease is a serious problem and is moving northward and areas around Kabba are hot spots. Thottappily et al (1995) reported that seven viruses are known on maize in tropical Africa, and MSV is widely distributed in sub-saharan Africa while the other viruses are less widely distributed or only of local importance. Mealie variegation or MSV is transmitted by leafhoppers *Cicadulina mbla* Naude. The symptoms consist of chlorotic streaking over and a long the veins on most of the leaf lamina. Though MSV requires the appropriate coincidence of inoculum source, vector and susceptible material, it can be very effective in ruining plants. At the very least, it severely limits times when maize can be planted in many areas (Johnson, 1975). In the case of both downy mildew and streak virus, resistance should be incorporated into promising QPM varieties as quickly as practicable. For us to accomplish this very soon, we require active cooperation of IITA.

With regard to insects, stem borers, the *Spodoptera* budworms, the *Heliothus* earworms and the stored grain insect can be regarded as the most important. In addition to their direct damage, the borers and earworms favour the invasion of ear and stalk rotting organisms. Insects are a major cause of maize storage losses in the tropics. They infest and damage grains, resulting in direct and indirect losses of both quality and quantity of food stored. The insect community associated with stored maize includes primary pests as well as scavengers, predators and parasites (Kossou and Borque-Perez, 1995). Damage and losses to stored maize in Nigeria are often severe. The difficultly of storing Opaque-2 was due mainly to insects penetrating the soft kernels. However, the cracking and splitting of the seed coat also foster decay. With QPM, storage damage is no worse than in ordinary maize because the endosperm hardness is virtually the same. A particular problem of stored QPM is aflatoxin. Though there is no unequivocal evidence that QPM is any more susceptible than normal maize to this toxin producing fungus, but like people, fungi respond to better nutrition (National Research Council, 1988). Jugenheimer (1975) observed that the germ of QPM seed with its high food value, is especially attractive to certain insects. Destruction of the germ is often the first injury resulting from attack by the grain beetle. The weevil, grain moth and lesser grain borer usually damage the grain as a whole.

Control Methods

Control of disease and insect involve breeding, use of chemical and cultural practices. Established insect problem require improvements in control, whether these involve plant breeding, parasites, predators, microorganisms, cultural practices or insecticides. Control of fungal diseases can be effected using chemical control, particularly the systemic ones. Naturally occurring biological control of maize insect pests should not be overlooked. There is also the need to assess the impact of production practices and selective chemical control measure in the population of parasites, predators and other entomophagous agents.

Control of stored grain insect involve sanitation, fumigation and use of various dust and sprays. Prevention is very important, and therefore for emergency problems, storage facilities may be fumigated with methyl bromide (Phostoxin). Grain protestants of low mammalian toxicity (malathion, gardone, and baythion) when use at a rate of 7.5 –15 ppm can provide effective control of the cosmopolitan granary weevil for over a year in tropical environment. A tight long husk cover has been shown to reduce weevil penetration and thus grain damage. The following insecticides are also recommended (g/100g maize grain): permethrin 0.5% dust (55g), deltamethrin 0.2% dust (50g) and fervalerate 1.0% dust (50g) (Kossou and Borque-Perez, 1995).

Resistance to fungal diseases has increased partly because QPM kernels are harder and dry more quickly than those of Opaque-2. It has increased also because the influences that cause the endosperm to shrink and the seed coats to split-which opens the kernels to infestations –have been reduced or eliminated. QPM materials resistant to MSV are necessary. According to Pixley (2001), almost all the available QPM germplasm from CIMMYT is susceptible to MSV. Similarly resistance to downy mildew should be developed to make QPM beneficial for areas where this fungal disease is endemic. Resistant varieties are the most practical and the cheapest solutions for control.

Resistance to MSV is controlled by 2 or 3 major genes and immunity to MSV have been detected in inbred lines and experiment hybrids. The resistant materials to MSV also showed resistance to other viruses. In the case of downy mildew, resistance is controlled by several factors and is additive in nature. Therefore, the breeding approaches that exploit the additive genetic variance such as full sib and should allow pyramiding of genes for resistance. If backcrossing is to be used where resistance is quantitatively inherited, it is necessary to include one or two generations of inter mating of resistant plants and their progenies between generations of backcrossing to maintain acceptable levels of resistance. Use of conventional backcrossing breeding as conducted for a qualitative trait, may not be successful because the level of resistance decreases with successive generations of backcrossing. For disease and pest resistance, artificial methods of infection and infestation are used to reduce escapes.

Cultivars Stability

Improved QPM materials generated in the breeding program must be capable of performing satisfactorily over a range of environments, or in other words, be broadly adapted. Adaptation to diverse environmental conditions can be gradually achieved through successive recombinations of superior genotypes identified at each of a series of sites representing the area for which adaptation is sought (Balint, 1970; Ado, 2000). The development of systematic analysis of varietal adaptation should be lead to identification of materials or groups materials with differing responses to environments. The next logical step in the development would be attempt to identify the specific environmental factors associated with the responses and to understand the morphological processes which are the bases of the different responses of the materials (Goldsworthy, 1974). Because varieties are not yet selected for all sites, current QPM varieties may not perform well in all environments especially those with specific disease or insect problems. Although current QPM varieties can approach normal yields, this may not necessarily be true for every part of the world. This is why we have started this evaluation of available QPM material for stability across our environment. Twenty-one QPM materials from lowland programme of CIMMYT Mexico had been obtained and are currently grown in five sites: Kano, Tiga, Dutsin wai, Samaru and Funtua. Other CIMMYT QPM materials obtained from Zimbabwe through the SG2000 had also been planted at the locations given above.

Questions concerning QPM's field stability, protein quality and endosperm expression would best be answered by more definitive research. It is true that in international testing, some QPM populations seem to be strongly influenced by climate and do not behave as expected. This is true of all crop varieties but in the case of QPM, the instability of the gene modifiers adds an additional uncertainty to be studied, codified and overcome (National Research Council, 1988). Modifier genes have been known to interact with the environment. The hard endosperm Opaque-2 materials tend to throw varying proportions of soft kernel. This effect is undesirable and suggests the need for bringing about stability for this character. Systematic progeny testing in different locations and eventually recombining only those families that are relatively stable for this character into new population is necessary. Genetic improvement in this manner will survive interaction with the environment.

he effects of sites on protein imply the joint effect of several factors, for example, soil type and weather. Of the agronomic practices, it is fertilization, especially nitrogen fertilizer which chiefly increase the protein level. The production of varieties responsive to higher nitrogen doses is associated with the production of varieties with higher protein level. It should be noted that a rise in protein content leads to a rise not in germ size, but in the endosperm protein especially zein, associated with a reduction of the ratio of the essential amino acids (Balint, 1970). According to Vasal (1974), environment influences quality of protein, but there Is little information as to its effect on quality protein maize grain. Alexander et al (1969) reported that lysine content expressed as per cent of total grain protein exceeds 5 per cent in several stock (inbreds, hybrids) and that environment apparently has little effect on relative level of lysine. However, for any quantitative trait, it is important to determine the magnitude of variation caused by location and year. Variation due to localities can be larger than that due to two different years and vise-versa. Large scale variability caused by environmental effects shows that breeders are faced with a difficult problem in their attempt to improve amino acid level in maize; .advances in breeding may be expected to lower variability, but will not eliminate it completely.

CONCLUSION

Although various approaches can be used to bridge protein gaps, one of the most feasible and economic solutions is the development of QPM. The improvement gained through breeding can provide the consumer with more nearly adequate amounts of nutritionally balanced protein without changing food habit and without additional food cost. Improvement of chemical composition of maize by breeding is difficult task. However the expected result will largely repay the required dividends for all the funds and energy invested. The choice of a particular breeding method depends on the breeding objectives and whether one or two populations are included. The breeding sequence for developing progenies, evaluating them and recombining superior ones to form the next population generally is the same methods of population improvement. By integrating new techniques with traditional methods, genetic improvement will continue to accelerate.

In order to develop a sustainable disease and pest management strategy for QPM we need to understand clearly the interactions among cultivars grown as sole crops and in association with other crops, the tillage practices adopted, planted densities, fertility level, pesticides levels and other cultural practices that may influence disease and pest incidences. Use of resistant cultivars offers an economically stable and ecologically friendly approach to minimizing losses from disease and pest. Economically successful QPM varieties are likely to create new unique and premium markets. Maintaining QPM's genetic purity in commercial production will then be of great concern. Maintaining genetic purity in production field and for monitoring protein quality levels in commercial practice is not only essential but absolutely necessary. One possibility can be the introduction of yellow QPM in areas where white maize is used and vice-versa. Use of hybrid QPM is another possibility since hybrid seed must be purchased for each planting. Genetic contamination can be avoided by developing QPM varieties that will be incompatible with normal maize by employing suitable incompatibility systems. From the available QPM introduced, the best can be chosen for immediate use until the superior one is identified or developed. The success of breeding programme is measured by the final product: a superior cultivar that is acceptable over a large area and provide an economic return on the investment in research and development.

REFERENCES

Ado, S.G. (1999). Maize Production and Food Security. Invited paper presented at the Workshop on Food Security, Social Mobilization and Community Empowerment held at Ahmadu Bello University, Kongo Campus, 3-4 November, 1999. pp.27.

Ado, S.G. (2000). Towards accelerated field testing and release of Quality Protein Maize Cultivars. Invited paper presented at a National Seminal on Promotion of Quality Protein Maize held at Institute of Agricultural Reserch, Ahmadu Bello University, Azria, December 19, 2000. pp.10.

Alexander, D.E.; R.J. Lambert and **J.W. Dudley** (1969). Breeding problems and potentials of modified protein maize. In : New Approaches to Breeding for Improved Plant Protein. Panel Proceedings Series. International

Atomic Energy Agency, Vienna. pp.55-56.

Anonymous (1969) New Approaches to Breeding for Improved Plant Protein. Panel Proceedings Series. International Atomic Energy Agency, Vienna. pp.193.

Balint A. (Ed.) (1970) Protein growth by plant breeding. Aademiai Kiado, Budapest. pp.179. CIMMYT. (1999). People and Parnerships: Medium-Term Plan of the Internation Maize and Wheat Improvement Centre. 2000-2002+.
Mexico D.C.: CIMMYT. pp.76.

Domanovic, J. and **M. Denic** (1969). Variation and heritability of lysine content in maize. In: New Approaches to Breeding for Improved Plant Protein. Panel Proceedings series. International Atomic Energy, Vienna. pp.109-116.

Fehr, W.R. (1987). Principles of Cultivar development. Vol.II. Macmillan Publishing Co. New York pp.1-10.

Frey, J.K. (1949). The inheritance of protein and certain of its components in maize. Agr. J. 41, 399-403.

Goldsworthy, P. (1974). Maize physiology. In Proceeding World Wide Maize Improvement in the 1970s and the Role for CIMMYT, April 22-26, 1974, Le-Batan, Mexico pp. 36.

Hallauer, A.R. (1987). Maize. In : Fehr, W.R (Ed.). Principles of Cultivars Development. Vol.II. Macmillan Publishing Co. New York pp. 249-293.

Johnson, E.C. (1974). Maize improvement. In Proceeding World Wide Maize Improvement in the 1970s and the Role for CIMMYT, April 22-26, 1974, Le-Batan, Mexico pp. 37.

Jugenheimer, R.W. (1975). Corn improvement, seed production and uses.
Urbana-Campaign, Illinois pp.670.

Kossou, D.K. and **N.A. Borque-Perez** (1995). Insect Pests of Maize in storage:
Biology and Control. IITA Research Guide 32, pp.28.

National Research Council. (1988). Quality-Protein Maize. National Academy Press, Washington D.C. pp.100.

Nelson, O.E. (1969). The Modification by Mutation of Protein Quality in Maize.
In: New Approaches to Breeding for Improved Plant Protein. Panel Proceedings Series. International Atomic Energy Agency, Vienna. pp.41-54.

Ortega, A. (1974) .Maize insects and diseases. In: Proceeding World Wide Maize Improvement in the 1970s and the Role for CIMMYT, April 22-26, 1974, Le-Batan
Mexico pp. 41.

Pixley, K.V. (2001). Protein Maize: Overview, breeding strategy and Recent Reseach Results for Southern Africa. Paper presented at a National Maize Workshop, Samaru, Zaria, Nigeria, September 2001 pp.16.

Thielebein, M. (1969). The world's protein situation and crop improvement. In:: New Approaches to Breeding for Improved Plant Protein. Panel Proceedings Series. International Atomic Energy Agency, Vienna. pp.3-6.

Thottappilly, G.; H.W. Rossel; N.A. Borque -Perez (1995). Viruses and virus diseases of maize in tropical Africa. IITA Research Guide 54, pp.36.

Vasal, S.K. (1974). Nutritional quality of Maize. In: Proceeding World Wide Maize Improvement in the 1970s and the Role for CIMMYT, April 22-26, 1974, Le-Batan
Mexico pp. 28.

TOWARDS ACCELERATED FIELD TESTING AND RELEASE OF QUALITY PROTEIN MAIZE CULTIVARS

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INTRODUCTION

The ultimate goal of quality protein maize (QPM) breeding program is development of cultivars that have high contents of lysine and tryptophan as well as high stable yield performance over environments. This goal is achievable in different phases. In the short term, introduced materials can be tested in multi-location and on farmer's fields to identify suitable cultivars for production within four years. In the medium term, improved cultivars can be developed as composites and synthetic varieties, while in the long run, adapted hybrids would be developed from the available germplasm. Quality protein hybrids developed could be better in terms of yield and quality protein than those currently grown. The responsibility for developing new varieties rests with the national agricultural research institutes and to some extent, the private seed companies. Improved population developed as potential cultivars must be evaluated before they are considered for registration and release to farmers. Usually the amount of testing depends on the breeding objectives, the purpose of release and the influence of the environment on the expression of the character being tested (in this case the content of quality protein). Quality protein being a quantitative character is expected to be strongly influenced by the environment. Qualitative characters such as disease resistance, controlled by a single gene, are not influenced by the environment, and limited evaluation in the greenhouse or field may be adequate.

Since maize is cultivated in a large scale in the country, initial informal or exploratory survey on maize production by researchers is not necessary. However study of secondary data to enable proper choice of a first set of QPM cultivars for on-farm testing and additional studies through focused (formal) surveys is necessary. Continued testing with a modified or new cultivars based on previous results is also necessary. Technical questions with regard to accelerated field testing of QPM varieties such as how to elucidate farmers wishes and understand their constraints, the type of experimental designs to use in the field testing, the techniques of data analysis to use and how the results obtained could be disseminated to farmers as well as to the scientific community at large will be highlighted by the paper.

FIELD-PLOT TECHNIQUES FOR CULTIVAR EVALUATION

Accelerated field testing and release of QPM cultivars can be achieved through well designed experiments which are carefully conducted, analysed and properly interpreted.

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Statistical technique are generally used for choosing appropriate experimental designs for error estimation, error control and proper interpretation of results obtained. The experimental error gives the difference among experimental plots treated alike and it is the primary basis for deciding whether observed differences are real or just due to chance. Experimental error is estimated by use of replications and randomisation while control of error is achieved through blocking. Proper interpretation of results is essential because results obtained are applicable only to conditions that are the same or very similar to that under which the experiment was conducted (Gomez and Gomez, 1984). Because of variation in time and space, trials with new QPM cultivars must be conducted in the research station, in multi-locations and on farmers field, to ensure that the results will apply over a wide range of environments before suitable ones are recommended for release to the growers. However, to accelerate the release of suitable cultivars, the first year of test can be limited to the research station and two or three other locations, while promising cultivars can be tested in multi-locations and on-farm in the second and the third years.

ON-STATION TRIALS

Preliminary trials with introduced QPM germplasm materials are conducted in the research fields. The main aims of the preliminary trials are to identify cultivars, lines or hybrids with production potential and to select the best ones to continue in the program. The lines that have specific deficiencies are eliminated at the same time. The preliminary trials are planted at the recommended planting time for normal maize, which Is usually between 1st to 15th June in the Northern Guinea savanna. The germplasm materials are compared with the cultivars that have been accepted by the farmers. Check varieties are placed at random or at regular intervals say at every 5 or 10 rows. Recommended production practices for production in term of cultural management practices are followed. Three seeds are planted per hole, about 3-4cm deep on ridges with inter-row spacing of 50cm. Thinning to two seedlings per stand is done two weeks after planting to give a population approximately 53,000 plants per hectare. Fertilizes are applied at a rate of 100-50-50kg N, P_2O_5 and K_2O per hectare, respectively. Weeds are controlled by appropriate methods such as manual weedings or use of pre-emergence or post emergence herbicides or a combination of them. Remolding is done to achieve weed control, improve soil aeration and prevent root lodging.

The trial is laid out in a simple lattice or in a randomised complete block design with 2 or 3 replications. The choice of design to use is to be determined by the number of entries included in the experiment and soil variability at the site. For 100 or more entries, the simple lattice design is preferred. However, further decision about the choice of an experimental design is made by comparing their relative efficiencies. If the lattice design is more efficient in reducing the experimental error by about 10 percent, the lattice design is used rather than the randomised complete block design. Plots in general are longer than their width and usually one to two unbordered rows are used. The row length is about 5.0m while row width is 0.75-0.90m. Inter-plot competition effects among entries in small plot trials, such as can occur. If cultivars of different maturity and plant height are in adjacent plots, the earlier, smaller cultivars will be at a disadvantage in comparison with the later taller cultivars. The effects of inter-plot competition; usually are kept to a minimum by grouping cultivars in a test by maturity and plant type, if large differences among cultivars are known for plant height within the same maturity, 3 or 4 row plots are used and data are collected from the centre rows (Hallauer, 1987). Data in the field are recorded for days to germination, plant stands after germination, days to tassel, days to silking days to maturity, plant height, ear height, root lodging, plant aspect and ear aspect while grain yield and protein quality are determined in the laboratory.

MULTI-LOCATION TRIALS

Because new cultivars will be grown under many different management practices and in environment conditions different from those found at the research station, promising genotypes selected from the preliminary yield test must be examined in as many different environments as possible in subsequent years. This is the responsibility of the breeder in conjunction with cooperators at the different locations. The multi-location trials are also conducted to determine the range of possible use and stability of performance over the geographic area in which the prospective cultivars are expected to be grown. About 10-20 locations for yield trials are considered each year. Three of the sites are selected for certain reason such, as Sudan savannah to test early maturing cultivars for short season. A site in the forest zone is chosen for testing the same short season cultivars for second season planting or long season cultivars for early planting. Other sites are chosen for testing cultivars under drought or other stress conditions.

The breeder or his institution nominates new cultivars into Nationally Coordinated Research Programme (NCRP) on Maize for the multi-location trials. New varieties for release must undergo at least two consecutive years of multi-location researcher managed trials. One year of multi-location testing may be accepted in exceptional cases when there is urgent demand, for example in the case of QPM (Oyekan, 1999). The multi-location trials are planted in 5.0m long plots with 2-4 rows. The 2-row plots are unbordered with both rows harvested for yield. Bordered plots are 3-row or 4-row plots with only the centre row harvested in the 3-row plots and the 2–center rows harvested in the 4-row plots. A sub-sample from the harvest of a plot is used for estimating protein quality. The most common design utilised for the multi-location trials is a randomised complete block design with 3 or 4 replications at each location. A simple lattice design with 2-4 replications can also be utilised if the number of cultivars exceeds 36.

ON-FARM TRIALS

On-farm research is used in examining the effect of physical, biological and socio-economic factors on the performance of different farming systems as well as test the acceptability or adoptability of new technologies by farmers (Mutsaers et. Al, 1991, Spencer, 1991). In on-farm research, new technologies are exposed to the real world of small scale farmer. On the farmer field, new cultivars have to cope with conditions which often have only a remote resemblance to those of the well organized and uniform experimental fields of the research station. Through on-farm trials factors influencing yield variability between field are analysed and the major yield limiting factors are identified. Integration of agronomic and socio-economic studies improves the efficiency of on-farm research and at times partly substitutes for costly experimentation (Byerlee and Tromphe, 1991).

On-farm testing is usually the final stage of the cultivar evaluation. The outstanding cultivars selected after multi-location trials must be tested for at least one year in farmer managed condition. This is usually carried out in collaboration with the State Agricultural Development Programmes (ADPs). The main objectives of the on-farm trials are to provide additional information in determining which cultivars are considered for release to farmers.

In designing the on-farm trial, ecological disparities must be addressed. Good use of secondary data concerning vegetation , soil and climate is made in the design of trials. Joint visits by scientists and ADP staff to monitor the trials at important stages of the crop growth are planned. The farmers reaction during the monitoring is noted (Erenie et. Al. 1991). The feasibility trials of the QPM cultivars is designed by both the researcher and the farmers. The involvement of farmers in the design and implementation of the trials improves the reliability of the results obtained because the farmers are interested in the outcome of the trials. Consequently common problems such as farmer's neglects of trial plots, obstruction of data collection etc. are reduced. Besides, this improves assessment because they understand the trials better and are aware of impute as well as outputs. Team and interdisciplinary work is improved when actual constraints are faced with the farmers. The results are easily diffused in case of success. Thus the on-farm trial if well designed may provide not only the intended evaluation of QPM materials, but may also supply breeders with information concerning selection criteria, pathologists and entomologist with useful data on the importance of significant diseases and pests at different times of the year, and may provide agronomist with information on a number of cultural practice issues as well as effects of various environmental factors on yield. If the trial is designed to conduct both farmer managed and research-managed on the same land; long-term on-station testing is unnecessary (Diomande and Tanom1991)

On-farm trials are usually non-replicated and are conducted on larger plots (0.25 ha). Maximizing the number of sites is generally more important than replications within sites. When testing the new cultivars, one or two level of fertility may be considered in the trial. Many important farmer related variables will show up during the trial. Therefore, a sufficient larger number of sites, say 20, is necessary in order to obtain the effect of this variability. A check is usually included in the trial as an adjacent plot on which the farmer grows the crop his own way. Labour cost is estimated to enable calculations of the profitability of the technology being tested. Information required from the on-farm trial include stand establishment after germination and final stand count before harvest, pest and disease scores, weed scores, maturity period, crop yields, plant and ear aspects, quality protein content, variable inputs, farmer assessment of the trial, etc. The farmers' assessment is obtained through group interviews, field days, follow-up surveys and test panels. If farmers are negative about a technology, it is unlikely to be adopted even if economic analysis shows it is profitable. A positive response by farmers need not, however necessarily imply that the technology will be adopted. Further evaluation is done after farmers have had a chance to evaluate storage, processing quality and marketability (Mutsaer et. Al. 1991). A complete analysis of agronomic and economic data enables a better assessment of recommendations for variety release.

RECOMMENDATION FOR REGISTRATION AND RELEASE

After one or two years of on-farm trials, the best cultivars with broad adaptation are recommended for registration and release. The data collected from all the trials used to determine the stability of performance of the cultivars. According to Findlay and Wilkinson (1963) stability of performance is assessed by regressing the varieties mean yields on the environmental index (the site mean yield).

The breeder or breeding institution sends the recommendation for registration and release of the cultivars through the NCRP coordinating institute to the Registrar, National Committee on Registration and Release of Crop Varieties and Livestock Breeds in accordance with Decree 33 of 1987. The submission made should contain general and specific descriptors of the cultivars as well as the performance data of the cultivars from the on-station, multi-location and on-farm trials. If release is approved, the cultivars will be entered into the National Register.

CONCLUSION

Accelerated field testing and release of QPM cultivars is possible if proper assessment of introduced germplasm is carried out . Proper field plot technique is needed in the conduct of on-station, multi-locations and on-farm trials. If funds are available for germplasm assessment in multi-locations and on-farm trials involve farmers in the design and execution of the trials; new cultivars may be identified, selected and released within four years. Further breeding work will, however, continue to improve the germplsm for hybrid variety development.

REFERENCES

Byerlle, D. and **B. Triomphe** (1991). The use of integrated agronomic economic surveys in the diagnostic stage of on-farm Research in Theory and Practice. Proceedings of workshop on design and analysis of on-farm trials, 27 February to 3 March 1989, IITA Ibadan pp. 23-38.

Diomende, M. and **K. Tano** (1991). On farm trial designed to stabilize an upland rice based cropping system in Cote d'Ivore. In: Mutsaers, H.J.W. and P. Walker (eds). On-farm Research in theory and Prctice. Proceedings of workshop on design and analysis of on-farm trials, 27 February to 3 March 1989, IITA Ibadan pp. 198-199.

Eremie, S.W., P.S.O. Okoli and **H.R. Chheda** (1991). An assessment of the design and analysis of on-farm trials in Nigeria's Agricultural development Projects (ADPs). In: Mutsaers, H.J.W. and P. Walker (eds). On-farm Research in theory and Practice. Proceedings of workshop on design and analysis of on-farm trials, 27 February to 3 March 1989, IITA Ibadan pp. 101 – 110.

Fibndlay, K.W and **G.N. Wilkinson** (1963). The analysis of adaption in plant breeding programme. Aust. J. Agric. Res. 14, 742 –754.

Gomez , A.C. and **A.A. Gomez** (1984). Statistical Procedures for Agricultural Research. Second Edition John Wiley & Sons, Inc. pp. 680.

Hallauer, A.R. (1987). Maize. In: W.R. Fehr (ed). Principles of cultivars development Vol. 2 Macmillan Publishing Co. New York pp. 249-293

Mutsaers, H.J.W.: J. Smith and **P. Walker** (1991). A synopsis of workshop concussions. In: Mutsaers, H.J.W. and P. Walker (eds). On-farm Research in theory and Practice. Proceedings of workshop on design and analysis of on-farm trials, 27 February to 3 March 1989, IITA Ibadan pp. 1 –22.

Oyekan, P.O. (1999). Variety Development, Testing and Release Mechanism in Nigeria. In: FAO/FDA/NSS Proceeding of comprehensive training in seed Production, Proceeding, Storage, Distribution and Marketing, Vo l. II, pp. 41-48.

Spencer, D.S.C. (1991). Collecting meaningful data on labour use and farm size for economic analysis associated with on-farm trials in Sub-Saharan Africa. In: Mutsaers, H.J.W. and P. Walker (eds). On-farm Research in theory and Practice. Proceedings of workshop on design and analysis of on-farm trials, 27 February to 3 March 1989, IITA Ibadan pp. 53-59

QUALITY PROTEIN MAIZE SEED PROGRAMME IN NIGERIA

T.O. Okolo*

1.0 BACKGROUND

1.1 Importance of Maize

Maize is a very important cereal crop in Nigeria, probably ranking third among the cereal crops. The 1998 Central Bank of Nigeria annual Report and Statement of Accounts stated that 6.4 million tonnes of maize was produced. Based on an average yield of about 1.3-1.4 metric tonnes/hectare, this means that about 5.0 million hectares of land is under maize cultivation. Maize is usually consumed green during the "hungry" periods immediately after the long dry season when tubers like yam and other food stuff become too scarce; it is also widely used as food by both man and livestock. Normal maize cultivars commonly grown and consumed are deficient in two essential amino acids, Lysine and tryptophan. As a result, malnutrition due to inadequate protein intake is, therefore widespread. To solve this problem, inter-institutional and multidisciplinary research was conducted with commendable result which have helped to:

i. Develop high yielding and stable quality protein maize (QPM) varieties which are high in these two essential amino acids, lysine and tryptophan, and
ii. Promote the production and utilisation of these cultivars.

1.2 Benefits of QPM

Quality Protein Maize (QPM) is relatively a new set of varieties of maize developed to improve on the protein content of normal maize, whose crude protein content is generally below 11%. The recent discovery of quality protein maize has made it possible to tremendously improve on the essential amino -acid composition from the plant kingdom. Studies conducted in Ghana have shown that:

i. QPM enhance linear growth in weaning children by 19.3% and
ii. Children fed on QPM had better chances of escaping death due to diarrhoea and other infectious diseases compared to those fed on normal maize.
iii. Cost per kilogramme feed was reduced by 29.4% for broilers and by 18.0%; 12.6% and 12.8&% at starter, grower and finishing phases for pigs, respectively, when QPM was substituted for normal maize in these diets.

There is significant difference when lysine and tryptophan content in QPM were compared with what is obtained in normal maize. The average of 4.005% / 100g of protein, for lysine in QPM and 2.96% / 100g of protein for normal maize was observed while that of tryptophan is 1.665g / 100g of protein as against 0.61g /100g of protein for normal maize. It follows that the main thrust of QPM development was to increase the essential amino acid content of maize, particularly the lysine and tryptophan content.

Because of the tremendous success of Obatanpa in Ghana, several other sub-Sahara African countries are testing the variety with

***National Seed Service, Abuja**

the aim of releasing it and improving on the nutritional value and therefore addressing the issue of resistance to stress and other biotic and abiotic conditions.

2.0 **State of QPM in the Sub-Region**

Quality Protein Maize is at long last, beginning to fulfil the promise that scientists originally saw in this type of maize when it was first discovered in 1963. QPM breeding materials, experimental varieties and hybrids were distributed to national research programmes and a few scientists - most notable in South Africa, Brazil and Ghana—by CIMMYT, Mexico. The SG2000 was instrumental in reviving QPM research at the Crop Research Institute (CRI) in Ghana starting in 1990. By 1993, an outstanding QPM variety based on CIMMYT material, had been developed and approved for commercial production. It was named Obatanpa, which means good mother. Since its release, Obatanpa has spread to more than 200,000 hectares of farmers' land in Ghana. Its high yield potential, excellent resistance to maize streak virus, which is a serious disease problem in most of tropical and subtropical Africa, intermediate maturity classification, and white grain type are all very much appreciated by farmers. Its broad breath of adaptation makes it suitable to many maize—growing environments. Obatanpa is being tested in most other SG200 project countries, with very good results and is presently being commercially grown in Benin, Togo, Burkina Faso, Mali and Guinea. In 1998, three, even high-yielding QPM hybrids were approved for commercial production in Ghana. Today, the emphasis of CIMMYT is more on developing hybrids, although new open-pollinated varieties are being generated as well.

The process of evolving QPM is based on conventional breeding process which is safe and environmentally friendly as against the genetically modified processes, whose technologies are still subject to controversy as they relate to the environment, human health, nutrition etc.

3.0 **Status of QPM in Nigeria**.

During the most recent visit of former President of the United States of America, President Jimmy Carter and his wife to Nigeria, the issue of QPM formed a very important part of their discussions with the Vice President of the Federal Republic of Nigeria, Alhaji Atiku Abubakar. The Vice President thereafter, directed the Federal Ministry of Agriculture and Rural Development (FMA & RD) to study the QPM in Ghana with the aim of introducing it to Nigeria. Consequently a team of two Officials of the FMA & RD undertook a study tour in Ghana between 2nd and 6th August, 2000. The outcome of their report culminated into setting up of a Ministerial Committee on Introduction / Development of QPM in Nigeria. The Committee's teams of Reference was to look into the detail modus operandi for the smooth, safe and sustainable introduction / development of QPM in Nigeria. The inaugural meeting of this committee was held at the Institute for Agricultural Research ABU, Zaria on the 30th August, 2000.. After extensive deliberations the committee came up with the following decisions:

i. The Committee agreed to introduce QPM into Nigeria, because of its inherent qualities of increasing the protein intake and enhancing the nutritional status of Nigerians.

ii. A virile National Seed Multiplication Programme for QPM should be put in place. This programme will be required to co-ordinate and monitor all implementing agencies (Public and Private) that would be involved in the cultivar development, multiplication, quality control, promotions, utilisations etc. of the various classes (Breeder, Foundation and certified Seed) emanating from the QPM Programme.

iii. Field testing should be accelerated to ensure that the requirements for varietal release are met within shortest time. Provisional release should follow laid down procedure.

iv. Existing legislation, rules and regulations governing germplasm introduction, variety development, release and registration should be strictly adhered to, but it should not stifle private sector initiative.

v. Need for compulsory certification of QPM seed was adopted, so that farmers are not ripped off and consumers interest protected.

vi The NARIs, NSS and Extension should be adequately and timely funded for successful implementation of the National QPM cultivar development, seed production/ distribution and promotion programmes.

vii. Prospective seed companies or interested seed producers desiring to partake in QPM programme shall be dully accredited for that purpose to ensure effective supervision, control and competition.

viii. The NCRP should be adequately strengthened to ensure accelerated release of proven QPM materials.

ix. Large scale importation of QPM seed from Ghana or elsewhere should be avoided for biotic reasons and other associated risks.

x. The NSS should meet very quickly with the two NARIs and come up with a costed National QPM Programme. This meeting was convened by IAR, ABU Zaria.

xi. Priority will be given to the installation of amino acid analysers already procured and supplied. At least two (2 No) analysers particularly at IAR and IAR & T shall be installed before the end of the year. Pending the installation, QPM materials shall be forwarded to a reputable testing laboratory for analysis. This should be done with approval of the Registrar of Crop Variety Registration and Release, through whom the materials will be forwarded to the agreed laboratory.

xii Whatever is sent outside the country for amino acid analysis must conform with the international phytosanitary procedures through the involvement of the Plant Quarantine service.

There is evidence that IAR, ABU Zaria collected germplasm of QPM seed between May and June, 2000 from Ghana Crop Research Institute. The IAR&T Ibadan also reported that three outstanding maize varieties that combine high yield with high protein content (about 14% total protein) as against the normal maize variety which contains 8-11% protein have been identified.

4.0 **Strategies for Virile QPM Programme In Nigeria**

i. The maize cultivars and hybrids currently in use by farmers are developed to solve the problems of Downy Mildew, Striga, Streak, Blight and drought. The incorporation of quality protein in maize seed sown by the farmers will be another monumental achievement if it takes cognisance of the need to include these advances already recorded in the normal maize into the QPM cultivars.

ii. The National Agricultural Research Institutes with national mandate for genetic improvement of maize should be adequately and timely funded to carry out germplasm screening and development of QPM cultivars adaptable to the various ecologies (forest, mid-altitude and savannah) of Nigeria.

iii. The National Co-ordinated Project on maize and the National Variety Registration and Release mechanism/committee should be well facilitated to ensure accelerated release of highly proven materials suited for any part of the country.

iv. A strong and very effective seed certification and Law Enforcement Scheme should be put in place in order to ascertain the quality of QPM in the market and arrest the situation of spurious and unscrupulous seed merchants who may wish to take undue advantage of the uninformed farmer.

v. All QPM cultivars shall be declared notified kinds for compulsory certification.

vi. A National Programme on QPM seed Multiplication, Promotion and Utilisation shall be in place to gradually replace normal maize with quality protein maize and ensure the maintenance of high quality in the purity of the QPM.

5.0 **QPM National Programme**.

The QPM National Programme shall:

a. Organise and co-ordinate the activities of relevant agencies (Public and Private) that will be involved in the screening, development, multiplication, promotion, distribution and utilisation of the various classes of seeds (Breeder, Foundation and certified).

b Ensure that a sustainable and phased programme with the ultimate goal of covering the total land area under maize production with QPM is achieved within the shortest possible time. The NSS, NARIs and the Private sectors should be given very prominent roles and support in this regard.

In pursuance of the decisions of the Ministerial Committee, the technical sub-Committee comprising NSS, IAR and IAR&T charged with the responsibility of developing a costed National QPM Programme met on the 19th and 20th September, 2000 at IAR Zaria. The sub-committee came up with a three year costed QPM Programme. The budget implementation schedule for the three year costed programme shall be at 50% during the first year, 30% in the second year and 20% in the third year. By the fourth year the entire programme shall be reviewed. On the claim that QPM seed is available in the country, the Government agreed that such claims should be ascertained and the varieties involved be analysed for their essential amino constituents. To actualised this, the two NARIs, IAR and IAR&T would be assisted by the Government to install their amino acid analysers before the end of the year. Currently. NSS is in possession of cost estimates for the required accessories which will enable full functionality of the amino acid analyzers and that for the installation / commissioning of the amino acid analyzer for IAR and IAR&T respectively. Concerted efforts are being made and available information showed that the release of funds has reached advanced stages, which will guarantee successful installation of the equipment for use before the end of the year, 2000. The verification of the essential amino acids of the available QPM in the country shall be completed within 6 months.

5.1 Implementation Strategies

Concerted actions are being undertaken to ascertain the locations of all established QPM seed fields in the country for proper follow up actions needed to mount effective quality control programme. The confirmed / certified quantities of Breeder, Foundation and certified seeds shall form the take off point for QPM use in Nigeria in year 2001.

SEED REQUIREMENT FOR A THREE YEAR NATIONAL QPM PROGRAMME

Seed	Class of Activity Within Quality of Seed to be Produced (kg.) 3 Years			
		2001	1002	2003
Breeder	1000 kg Produced by IAR IAR&T	500	300	200
Foundation	25,000 kg Produced by NSS	12,500	25,000	15,000
Certified	=N= 1,000.000			

** = Quantity of QPM seeds to be sourced outside the National QPM Programme during the first two years of the Programme.

The development of QPM including germplasm collection, evaluation, screening/ selection and Breeder seed production already initiated by IAR and IAR&T shall be completed within three years programme with production of 500kg Breeder seeds of two QPM cultivars per institute. Similarly On-Farm testing / NCRP evaluation nation-wide with ADPs, NSS and FDA shall go on currently. The NSS shall produce Breeder seed from any Seed Company having duly accredited materials. Within the three year programme NSS shall be funded to procure 25 metric tonnes of Foundation seeds while price support of about =N=1, 000,000.00 shall be provided to enhance uptake of certified QPM seeds by farmers.

5.2. **Price Support**

To ensure quick and adequate uptake of QPM seeds by farmers, a price support regime is envisaged to make the seeds affordable and this shall be implemented in line with the budgetary provision of 50% support in the first year, 30% in the second year and 20% support in the third year of the programme.

6.0 **Seed Certification and Quality Control**

The General Seed Certification Standards which are basic and together with the specific field and seed standard shall constitute the standards for the certification of QPM seeds. For the production of Open-Pollinated QPM cultivars, a minimum of three seed field inspections shall be conducted in such a way that the first is made before flowering, the second during flowering and the third just before the harvest. In the case of the production of QPM inbred line, single, three way and double cross hybrids seeds, a minimum of four seed field inspections shall be conducted in such a way that the first is made before flowering, two during flowering when the seed crop has apparently 5% or more receptive silks in the seed parent rows (hybrids) and the last before the harvest.

Only seed lots that meet both the prescribed field and seed standards, granted certification, well labelled and packaged with affixed certification tag shall be allowed to be marketed. This shall be assured through regular seed quality checks, assurances and control on all categories of QPM seeds in seed stores across the county in order to safeguard the interest of the uninformed farmers from paying for spurious seeds and curtail the activities of unscrupulous seed dealers / merchants.

7.0 **Seed Promotions**

QPM adoption and utilisation promotion programmes to create needed awareness on the nutritional qualities inherent in QPM to enhance rapid uptake by the end users shall be accomplished through these strategies:

i. **Demonstration**

Using the MTP approach of SG 2000, with a plot size of 0.25 ha, provision of agro-inputs (seed, fertilizers, agro-chemicals) on time, 10 N0s. Demonstration plots, to be farmers managed, shall be established per state and the FCT during the first year of the Programme.

ii. **QPM Workshops**

Two workshops with the objectives of enlightening the policy makers and all stakeholders including the participating ADPs, Women-in-Agriculture, Home Economic Division, Ministry of Health, UNICEF, SG2000 and agro based industries on the utilisation and benefits of the QPM shall be carried out. One in IAR, Zaria for the Northern States and the other at IAR&T, Ibadan for the Southern States.

iii. **Publicity**

a **Production of Advisory Leaflet on QPM**

Advisory leaflets in English language, and three Nigerian languages, including Posters, Hand-bills shall be produced in collaboration with NAERLS.

b **Radio Jingles**

Radio jingles in three Nigerian languages and English language shall be developed by NSS in collaboration with

NAERLS, Women-in-Agriculture and Home Economic for use during sponsored air time to convey specific messages on QPM to the grass-root.

c **Documentaries**

Television documentaries in the third year of the programme on the achievement of the QPM programme shall be produced.

iv. **Community Seed Diffusion Programme**

The federal Government may consider the option of procuring a given quantity of QPM seed for distribution to the States and FCT for planting, following the SG2000 MTP model during the second and third year of the programme.

8.0 Monitoring and Evaluation

Effective implementation support in terms of adequate monitoring and management information services would be provided. In addition, baseline survey and impact evaluation studies would also be conducted.

9.0 CONCLUSION

In conclusion, therefore, the biotic and abiotic problems peculiar to the diverse agro-ecologies of Nigeria will have to be overcome e.g. Downy Mildew, drought tolerance, Striga, Blight etc. importation of QPM materials except for germplasm purposes should be pursued with caution, because of its adverse consequences. Adequate and timely funding of the National QPM Seed Production, Promotions, Utilisation and Distribution Programme should be accorded top priority so as to ensure proper co-ordination and monitoring of QPM dissemination into the rural farmers throughout the country.

SEED PRODUCTION AND MARKETING: THE SEED CO EXPERIENCE

S.B. Mc Carter*

INTRODUCTION

Effective maize breeding in Zimbabwe created the need to create business structures to multiply and market superior hybrids. The seed company created has successful to the point that large volumes of adapted, high quality seed have been made available and are purchased annually by smallholder farmers. The almost total adoption of hybrid seed would tend to indicate that these are ready to apply reasonably priced improved technology.

SEED CO MISSION STATEMENT

Critical Success Factors

- The development of superior leading products through innovative research and access to the seed industry's best technology.
- Commitment to customer satisfaction and the enhancement of farmer productivity and profitability.
- The recruitment and development of skilled employees and their retention through rewarding output, talent and integrity.
- The efficient co-ordination and management of the seed supply chain, from seed production and processing through to the distribution network.
- Sound financial management and information systems to ensure continue business viability and growth from a strong financial base.
- The development of new markets of new markets and the expansion of the company's sphere of operation.

Achievement of this mission will ensure a sustainable and profitable business providing acceptable returns to our shareholders, while significantly improving food security in the region. It is important to note that while the company was born in Zimbabwe the mission is to extend operations to all appropriate markets in sub-saharan Africa. The company's marketing theme for 2001/2002 embraces the simple statement £Seed Co-Feeding Africa".

SEED CO LIMITED - THE RESULT OF EVOLUTION

The origin of Seed Co in Zimbabwe date back to 1940, with the formation of the Seed Maize Association. This Association was requested by Government, to multiply and market popular open pollinated maize varieties. This group of far-sighted maize growers recognized the vital importance of seed quality and supply. Together, these members have ably produced consistent quality, hybrid and open pollinated seed in sufficient volumes to sustain Zimbabwean and Regional needs even after recent droughts.

The Crop Seed Association was formed in 1957 initially to concentrate on improved wheat, soybean and groundnut seed production. Later developments embraced the sunflower, sorghum, millets, barley and bean seed crops.

In 1988 the Zimbabwe Seed and Crop

***SEED CO LIMITED, P.O. Box WGT 64, Westgate, Zimbabwe**

Seed Associations merged to form the Seed Co-operative Company of Zimbabwe Limited. Having similar objectives, this rationalisation provided for more efficient resources use and consolidation of like interests. Membership and staff were amalgamated which resulted in a single management structure where all research, production, conditioning, warehousing, marketing and financial support were streamlined.

Seed production volumes continued to increase and in 1990, it was realised that plant, building and equipment were inadequately coping with growth. Relocation took place the following year to a 10 hectare property at Stapleford, some 20 kilometres north of Harare.

These new facilities comprise a three-hectare warehouse (including an Export Processing Zone), a parent seed store, government-approved seed testing laboratory and Head Office. State-of-the-art seed conditioning equipment has been installed to ensure the timely delivery of quality seed to our customers. Small packing equipment has, in recent years, been stretched beyond the limit of its capacity in providing customers with a large range of pack sizes to meet their individual requirements.

In mid 1996 the company was renamed Seed Co Limited and was listed on the Zimbabwe Stock Exchange. This significant event would:

- Make shares available to all interested investors.
- Provide the mean to raise capital
- Make management more accountable for the company's performance
- Facilitate the development of regional Business

This evolution of Seed Co was precipitated by the increasing complexity of seed production, rapidly increasing seed volumes, changing economic conditions and the need to complete with global players. What started in 1940 as a relatively significant grouping of far -sighted maize growers has evolved over 60 years to the largest seed company in the Region.

In order to bridge the gap for resource poor farmers, between research and field application of appropriate technology, linkages need to be created and nurtured. The combined resources of CGIAR Centres, NARS, NGOs, donors and the private sector will need to be focused specifically at raising productivity at smallholder level. Seed Co works effectively with CIMMYT, ICRISAT and SG2000 in a range of projects and crops... resources are too limited for any of us to do it alone!

RESEARCH IN ZIMBABWE

Research focused on breeding hybrid maize began in 1932, at the Harare Research station which is still today, part of the Ministry of Agriculture. This remarkable event placed Zimbabwe as the second country in the world, after the United States, to embark on a hybrid maize breeding programme. The first commercial maize hybrids were released by the station and introduced for sale by the Seed Maize Association in 1947. SR52, the world's first commercial single hybrid cross, was officially released in 1960. The hybrid is grown in small volume in the region.

An important key in the development of the Zimbabwe seed industry was the signing many years ago of the legal agreement with the Ministry of Agriculture. This agreement entitled the company the exclusive right to multiply and market a range of Government bred products. In exchange, the company had to undertake to produce agreed volumes of seed, including a 20% to 30% carry-over, depending on seed type and to sell the seed at agreed prices. These agreements have resulted in large volumes of quality seed being made available to Zimbabwean farmers at prices three times lower than those in South Africa and appropriately to the farming community on the basis of royalty paying agreement with a number of seed companies including Seed Co.

ONGONIG COMMITMENT TO RESEARCH

Acknowledging the importance of crop breeding development and to provide a mid-attitude testing site for Zimbabwe Government breeders, Seed Co bought a 300 hectare farm in Arcturus in 1973. Named the Rattray Amold Research Station, this private facility, funded entirely be seed sales, has since provided the company's with appropriate breeding and testing facilities on range of crops.

A company committee comprising breeders, production and marketing expertise studies reports and data presented before release for commercial use is considered. Higher yield, improved disease tolerance and product adaptability to meet certain market segments are vital criteria and usually reflect at least three years of multilocation testing and demonstration under field under field conditions. Release for commercial is only proposed for more of the critical criteria show significant improvements over currently available products.

The Research Stations are a show-piece of professionalism and is not the only site used to evaluate germplasm. Extensive trials are carried out country-wide, in both large and small scale farming environments. Collectively, in 2000/2001, over 700 scientific trials on over 1000 000 field plots were planted and will be analysed before next summer. In addition, demonstration blocks at approximately 200 sites featuring newly release materials are grown and used effectively for field day events.

More resources are being allocated to research activities. The number of breeders employed has increased to 10 and additional financial and technical support has followed Research needs to be market driven customer focused and cost effective and should cost a minimum of seven percent of net revenue.

With frequent droughts, a new breeding emphasis has been placed in the development of drought-tolerant crops and varieties. Since Rattray Arnold Research Station is situated in a high potential farming area a second station was purchased in 1996 at Kadoma, (Zimbabwe) a warmer, dried and lower potential environment, which will provide the conditions needed to breed such varieties. This development will enable the company to better serve the needs of small scale customers and to remain competitive in this most importance market.

The two research stations in Zimbabwe are both suitable for the development of maize hybrids adapted to mid-altitude conditions. In order to supply hybrids adapted to lowland tropical conditions a third breeding programme is now conducted near Maputo in Mocambique.

In order to provide a foundation for business in countries in sub-Saharan Africa where maize is an important food crop an extensive testing programme is conducted.-this programme involves observation and critical trials of both release and experimental cultivars expected to perform in the target environment. Cultivars with outstanding yield potential are targeted with additional strength in the areas of drought and disease tolerance (grey leaf spot, maize streak virus, rusts, leaf blights and cob rots) improved plant type and grain quality (dent/flint, white/yellow and Quality Protein Maize/normal types. The aim of this process is to identify superior products for farmers use and to secure national release/registration to enable sales to commence.

HOW TO DOUBLE SMALLHOLDER YIELDS IN TWENTY YEARS

Significantly increasing yields in smallholder farm is a task we need to apply ourselves to if we are to feed for people for twenty years and to ensure basic food production as a platform on which other developments may take place.

The development, deployment and adoption of affordable and sustainable technology is the key to raising productivity of resource poor farmers. A number of studies have demonstrated that over time approximately 50% of yield grains in farmers' fields are agronomic and 50% genetic. There is a long list of issues that need to be grappled with. It may, however, be appropriate only to mention a few that may likely be addressed by a group of agriculturalist;

- Water conservation technologies
- Improved agronomy practices (planting dates, weed control etc.)
- Soil management
- Insect resistance
- Cultivars better adapted to low soil fertility and drought.
- Cultivars more tolerant to root, stalk, leaf and grain diseases.

There is need to develop for different ecologies and economic situations appropriate "best practices". These practices need to be understood and supported by all who address the needs of smallholder farmers. On the back of these "best practices" breeder should use appropriate breeding techniques to develop cultivars that will be more productive under conditions encountered by the Regions farmers.

SEED PRODUCTION

Seed Production division is the 'sees factory' of the business and is responsible for the production of large volumes of seed requested by the Marketing Division.

After release by the Research Division, limited quantity of breeder's seed is provided to the Parent Seed Department Subsequent production cycles will involved seed growers in multiplication for the company of approximately 50 000 tonnes per annum. All this seed is produced to conform to the requirements of the Seed Certification Scheme and is monitored by a large group of company employed, but Government approved, seed inspectors and quality control laboratory. The whole scheme is 'policed' by Seed Services as the responsible Government agency.

In addition, in pursuit of enhanced quality and customer service, the company has embarked on a total quality management programme and was awarded ISO 9001 certificate in November 1999.

The Members of the Zimbabwe Crops Seed Maize Association produce much of Seed Co's seed requirements. This structure provides a reliable, consistence and permanent production base which is extremely cost effective. Grower viability has been maintained whilst seed selling prices are some of the lowest in the world.

For the past six years over one thousand small scale farmers have been involved in the production of sorghum, millet, cowpeas and groundnut seed. (Note these are crops where isolation distances are less of an issue than they are with maize). This exercise has increasingly involved small farmers in see production while also providing Seed Co with a more consistence supply of these seeds. This is more potential to increase utilisation for this producer base and seed Co is willing to work through third parties (NGO's) etc.) or to provide quality foundation seed to facilitate community based or contract seed production relationships.

In harmony with the company's Mission Statement to develop the business increasingly in sub-Saharan Africa, seed is currently being produced in Malawi, Mocambique, south Africa, Uganda, Zambia and Zimbabwe. As product registrations are achieved and business opportunities occur the list of seed producing countries will be expanded.

OPERATIONS

The Operations Division is the service centre of the company with responsibility for seed deliveries, processing, storage, small packing, despatch and overall 'housekeeping' of these valuable products, worth of millions of dollars.

Seed maize is delivered either ready for sale or in its raw state. The Operation Division small packs millions of units into 10kg., 5kg, 2kg and 1kg pack sizes. The plant used for this massive exercise has appropriate capacity to meet the requirement of the market during seasonal peak demand periods.

Other crop seed are delivered after harvest as raw seed and required conditioning. State of the art equipment (CIMBRI/HEID) has been installed to facilitate this conditioning plants consist of pre-cleaner, gravity table, sizing tower (for maize) treater and bagging unit.

The warehouse has road and rail facilities which caters for incoming and outgoing stock movements. This flexibility assists in reducing equipment has been positioned in Mocambique and Zambia. Currently facilities are being rented in Malawi and South Africa while production in Uganda is effected by an agent.

It is considered vital in a competitive market that funds are continually allocated to the provision facilities and plants to enable the company stay ahead. This is particularly true in times of draught, high interested rates and economic instability.

THE DEVELOPMENT OF THE ZIMBABWE MAIZE SEED MARKET

Once the first double hybrids were released in 1994, adoption was so rapid by commercial farmers that are more than half the commercial crop was planted to hybrids within two years. The release of SR52 in 1960 further stimulated the use of hybrid seed and by 1970 98% of the commercial area was planted to this hybrid. This coincide with development of the fertilizer industry and the widespread application of fertilizers and improved management practices on maize. Consequently between 1949 and 1970 commercial from approximately 1 t/ha.

With the release of short season maize hybrids in the early 1970's adoption of hybrid seed by smallholders grained momentum. The area planted to maize by these farmers increased from 600 000 ha in 1979 to 1 074 000 hectares in 1986, a 79% increase, yields achieved over this period rose approximately from 0,7 to 1,2 t/ha.

Today, almost 100% of smallholder maize is grown to hybrid seed and is sold in park sizes between 0,5 to 25 kg. Everybody, irrespective of plot size purchases hybrid seed!

There were a number of factors that have contributed to this remarkable story;

Return to peace and political stability at independence in 1980

- Attractive commodity prices
- Effective commodity purchasing and payment by the Grain Marketing Board
- Commitment and field demonstrations by the Government extension agency
- Cost benefits are clearly evident even to smallholder farmers
- Production and wide distribution of small packs of seed at relatively low prices
- Appropriate seed legislation
- The presence of a seed company with the vision to expand its business

The success of this model both can, and needs to be repeated in other developing countries. It needs to be stressed that this process has taken time and the development of appropriate private/public sector partnerships. Particularly in the initial stages of market development the private sector is going to require assistance/incentive from the public sector.

MARKETING ACTIVITIES

Like many African companied, seed Co was until recently production driven. Good quality products, bred and adapted for local Zimbabwe growing conditions, sold themselves. Increasing competition and the need to develop new markets has provided the impetus to shift to meeting the needs of the customer.

Extension field promotional work is now a major focus with over 200 demonstration sites planted in the 2000/2001 season largely in the communal farming sector. These sites are used to facilitate a massive field day programme where farmers and trader can seed and evaluation new off-season. These programmes address an estimated 70 000-100 000 farmers annually.

Improved farming practices are actively encouraged through sponsorship of the annual National Crop Farming Competition for small scale farmers. Winners have shared knowledge and experiences with their counterparts which has been beneficial to farmers generally.

Distribution of all seed types and pack sizes pose the biggest challenge to effective seed marketing. With a short, concentrated selling season, lasting around 12 weeks, seed needs to be timeously placed closed to farmers throughout the country. Several complimentary strategies are used to achieve early seed distribution, including a number of Seed Co Depots. From depots the seed usually passes through a wholesaler before reaching retail stores widely distributed throughout the area where maize seed is required. It should be stressed that sales to smallholder farmer is largely on a cash basis with minimal outside financial intervention.

In 2000/2001, 10 new maize hybrids, one soybean and two wheat varieties were placed on the market and required special promotion to make them known. A sponsored vernacular radio programme has provided a link, directly with farmers who write in to the presenter with questions and request for advice on achieving better farming results. Greater consumer contact is needed where modern marketing techniques move from the mass marketing systems toward small, focused customer groups and even individual in the more personalised touch that is expected today.

Point of sale material, signage and consumer competitions have recently generated valuable trade alliances within the distribution chain.

Comprehensive literature is a critical vehicle for information dissemination and this is used extensively to reach as many farmers as possible. They constantly use reference material and want to stay with new products and their characteristics.

All these activities are designed to provide a focus on the customer whose custom is required on an annual basis and should assist in raising productivity at the household level. It should be noted that the amount of finance provided to promotion related activities matches expenditure on research. The point is that good research and the resultant good products need to be adequately promoted if farmers are to adopt the improved technology.

REGIONAL BUSINESS DEVELOPMENT

For many years the company exported significant volumes of seed into Regional markets.

This Regional market is many time the large Zimbabwean market and provides the company with the opportunity to continue to expand its business in the face of increasing competition in the home market. The company's products are well adapted to much of the mid-elevation ecology in the Region and an aggressive testing process is needed, in particular, to expose newly released material to these markets. In addition, for export, only strategy of the past has been replaced by a will to develop resident seed business within targeted countries. In recent years a subsidiary has been established in Zambia, Botswana, Malawi and a 51% share of SEMOC in Mocambique has been purchased and a joint venture with Syngenta in South Africa established. The company has both the need and the desired to regionalise its business which should ultimately also enhance the availability of superior products for farmers throughout the Region.

FINANCE SUPPORT

With high prevailing rate of interest, inflation, economic instability, droughts and the consequential escalation in the prices of agricultural commodities, it is vital that more attention is paid to correct financial structuring. High level of financial expertise are needed to cope in this difficult environment and the injection of additional capital is considered necessary to take hold of new opportunities and to maintain a competitive edge in our core business. In addition realistic margins need to be realised on sales to sustain the business in the long term.

The 1996 flotation and listing on the Zimbabwe Stock Exchange was in principle driven by the need to strengthen the company's financial position. In addition, significant funds were raised to finance additional seed cleaning and packing equipment and the Kadoma Research Centre. Additional shares were subsequently issued to finance investment in SEMOC and for the establishment of our Export Processing Zone (EPZ). The EPZ has some tax advantages but has plant and equipment that will enable the processing of seed to international standards for the companies increasing export markets.

The opening of a subsidiary in Botswana has enabled the company to operate in a hard currency environment and has facilitated the raising of finances to fund the expansion of the business in the Region.

The company had a turnover of approximately USS32,0 million and made an after tax profit of approximately US$4,8 million in the year ended February 2001.

SUMMARY

A number of key elements may be identified in relation to past and anticipated success.

- Build continually on past performance
- Research and development is long term and the heart of the business and must adequately funded.
- An unwavering commitment to quality is required by all customers.
- Provision of adequate facilities and plant is essential.
- Marketing must be driven by the needs of customers
- Correct financial structuring may dictate success or failure

Access to finances, facilitates and germplasm are essential to the success of many seed business. However, people remain our greatest asset. Seed Co seeks to employ, develop, retain and adequately compensate the best available talent in the seed business. If there is any single secret to success in the seed business-this is it!

THE ROLE AND CHALLENGES OF AGRICULTURAL EXTENSION IN NIGERIA IN THE 20TH CENTURY

Jacob P. Voh and T.K. Atala*

INTRODUCTION

Agricultural Extension in the 20th Century

The underlying purpose of extension anywhere is to facilitate technological change at farm level, which would enhance the productive capacity of the farm and its operators (Pretty, 1995). Hence the role of extension has been the promotion of economic and social development in the rural areas. The economic goals are raising production and productivity while the basic social goal is equity between regions, communities, households, men and women, age groups and individuals (Garforth and Harford, 1997).

In the 20th century, increasing food supply became the central goal of agricultural extension in Nigeria and elsewhere in the Third World. This led to neglect of small mixed-farming systems. Government extension organizations listened to researchers and not to the farmers. As a result, the technologies developed did not fit the needs and interests of small-scale subsistence farmers. Agricultural research emphasized irrelevance of extension to small mixed farming systems. The NGOs with their human and family-welfare approach were, however, few and limited to small areas.

In the last half of the 20th century, agricultural extension systems shifted away from the multiple roles, which registered great successes, into extreme emphasis on new technology delivery to farmers. According to Axinn (1977), the opportunity for long-range rural development of which aim was to organize groups, empower farmers, pursue equity and sustainability of fields and rivers was ignored.

There were basically two major roles of extension to farmers, namely technology transfer, i.e. to recommend to farmers what to do, and to provide advisory service, i.e. to provide information to farmers that gives them options for their decision making. The important role of facilitating change through experiential learning and acquisition of skills such as problem solving, organizing and motivating farmers was not emphasized.

Extension activities were associated with government extension agencies. There was no perception or recognition of extension activities as being performed by research institutes, private companies and even farmers and farmers groups. Projects sponsored by international donors had many problems of their own, including high recurrent costs, which threatened sustainability of the projects, insufficient understanding of the local context, imposition of approaches and insufficient time for institutional building (Garforth and Harford, 1997).

Changes in Agricultural Extension in the 20th Century

Changes are inevitable in all aspects of life. Therefore, the important concern is not change but how to respond to change. In the Nigerian agricultural scene, much change has occurred since during the colonial era. Some of the general changes that have taken place which relate

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to agricultural extension are briefly discussed hereunder.

Natural Resources Management, Sustainability and Extension

Earlier in the twentieth century, people were aware of the fact that natural resources were not unlimited or inexhaustible and that there were limits to development and growth. However, there has been a growing concern over sustainability of farming systems and widespread deterioration of the physical environment on which agriculture depends. The concerns over soil conservation are brought about by deforestation, soil erosion, desertification, pollution and over-extraction of surface- and groundwater, dependence on non-renewable petroleum, and the inappropriate use of agrochemicals (Pretty, 1995).

Traditional individual farm orientation of extension work has been challenged by the concerns on natural resource management and sustainability. With increasing focus on natural resource management and sustainability, the importance of group and community involvement in extension has been highlighted. The issues involve social forestry, communal range management projects, land use planning, watershed planning, communal resource use (e.g. water), and integrated pest management. All these require formations and teamwork of other professionals and stakeholders.

Partnership and Inclusion in Extension

In the past, extension was associated with only government extension systems. Other stakeholders in extension delivery were not given due recognition. Now it has been increasingly realized that farmers require information regarding various aspects of farming including marketing, prices, etc. and that no single entity can solve the problems of relevance, quality and sustainability alone. All stakeholders including NGOs, agribusinesses, CBOs, cooperatives, user associations and donors must be involved. The realization for change is as a result of liberalization, democratic governance, decentralization and devolution of power and financial constraint.

Extension methodology

The traditional extension methodology has been the diffusion and adoption or technology transfer mode of extension services. In this method, new or recommended technologies are passed on to extension agents who then pass them on to farmers, who go through a long decision-making process after which they adopt or incorporate the technologies into their farming systems. Now the trend towards interactive and experiential reflexive experiential learning has given a new direction to technology development and uptake.

Extension education

Traditional extension education is characterized by high content of theory and in-class and laboratory activities. There is little fieldwork or practical skills, lack of concern with the labour market pressure or employers' needs. Yet universities and colleges should be at the cutting edge of knowledge as well as transmit relevant knowledge to the people and train the cadres needed for modernization. However, there have been changes that impact on and pose challenges to agricultural education. These include globalization, downsizing of the public sector, biotechnology, urbanization and information technology. These must be taken into account in developing relevant and responsive or demand-driven extension education curricula.

According to Friedman (1999), globalization is the integration of markets and technologies that enables individuals, corporations, and other organizations and nations to make decisions faster and cheaper than ever before (Knipscheer *et al*, 2001). For the Nigerian farmer, it means change of orientation from local market and local competition to global market and competition for their farm produce, farm inputs and research and extension services. To be competitive, farmers must have access to global technologies. Therefore, extension should serve as the key facilitator and should be able to introduce new technology and market options to farmers.

Downsizing or reduction in the size of extension field staff took place in line with the general downsizing of the public sector in Nigeria. This implies an increasing role for the private sector and need for searching for alternatives to the fully public funded extension system such as service-for-fee systems or close linkages with private sector organizations (Knipscheer *et al*, 2001).

Biotechnology and urbanization

A lot of new technology is being generated through biotechnology research which extension must know of and pass it on to farmers for their uptake. This necessitates use of new information technology at research, extension and even farmer levels. Urbanization effect on rural agriculture, and urban agriculture are also changes that have applications for extension services.

The Role of Agricultural Extension in the 21st Century The Role of Agricultural Extension in the 21st Century

Up till the middle of the 20th century, the idea of participation was not widely accepted. Top-down authority was the cultural and political norm, especially by those in power. Extension has been largely a top-down delivery approach in which others decide what farmers need to know, and attempt to deliver it to them. This has failed in the small-scale mixed-farming systems. It is now realized as reported by Uphoff, (1992) and Chambers, (1993) that top-down approaches are much less effective than participatory, farmer-centred approach whereby farmers participate in determining the agenda, the content, the communication channels to be used, and even the personnel to staff the system (Axinn, 1997). This should guide extension in the 21st century.

The Structural Adjustment Program introduced in Nigeria in 1986 to restructure the country's economy attempted to reduce the main roles of extension and research to facilitative and qualitative roles and divest the important roles of input supply, credit and seed multiplication to the private sector. The program also led to reduction of the number of government extension staff due to the decline in the level of State expenditure.

As it is, the role of the public sector extension system needs redefining because of cost consideration and the limited success of the single-system approach. There should be a clear extension strategy which encompasses the adoption of multiple approaches to extension. The public sector should divest itself of the aspects of extension which the private sector can handle such as service provision and input supply.

Instead of feeding the farmers with the new technologies which were not part of their development, the farmers are to be assisted in identifying constraints, problems and opportunities on their farms and in obtaining information and other support for solving the problems and in taking advantage of opportunities, through interactive and experiential learning. This new perspective entails greater interaction and dialogue, the use of participatory methods and recognition of indigenous knowledge and how farmers compare options, minimize risk, adapt practices and seek information (Garforth and Harford, 1997). It ensures that the technology is appropriate, recognizes adaptation rather than adoption only and it is built on sound principles of adult learning and partnership.

The new approaches of extension that are central to the changing role of agricultural extension have been delineated and explained by Röling (1995). These approaches are as follows:

- village groups for participatory technology development
- local organizations for improved socioeconomic positions
- platforms for sustainable natural resource management
- agricultural technology systems for technology innovations.

These approaches are based on the framework of the Agricultural Knowledge and Information System (AKIS) which is a novel and coherent perspective on agricultural innovation and knowledge management and emphasizes on the creation of articulated networks of actors that synergistically support innovation in a given area of activity. The methodology that has been used for AKIS studies is the Rapid Appraisal of Agricultural Knowledge Systems (RAAKS).

Village groups participatory technology development is a counter approach to the past (failed) centralized organizational and technology delivery set-ups that developed blanket recommendations for individual crops and uniform technology packages for large recommendation domains (areas). The centralized approach did not consider the complexity and diversity of local farming systems with highly variable conditions. It also neglected minor crops and ignored intercropping, household food security, complexity of livelihood systems, the role of women in food production, use of local resources and local knowledge (Röling, 1995). To address this problem, agricultural extension role must change to become a decentralized knowledge system which works with groups of local experimenters.

Local organizations for improving socioeconomic positions approach is premised on the fact that the key aspect for small-scale farmer development is the organization of small-holder farmers for understanding of problems, mobilization of local resources, innovations, and a powerful voice for support and counteracting exploitation and oppression. Therefore, extension intervention should involve mobilization, training, opportunities and system management. Hence arrangement involving farmers groups, GOs and NGOs is required for small-holder farmer development.

The platforms for sustainable natural resource management approach emerged out of the realization that traditional extension work tackles three agricultural development objectives - food production, productivity and equity - without tackling sustainability or protection of the resource base which requires focus on larger system than the farm, large time horizons than a growing season and focus on groups of stakeholders in natural resources (eg. villages or groups of villages). Hence managing entire agro -ecosystem is a new role required of extension organizations.

The agricultural technology systems for innovations approach is a counteraction of the linear or the technology transfer model which has failed because farmers are not passive receivers of scientific idea. They are active researchers and experimenters themselves. It is therefore now realized that active involvement of farmers in research and extension is necessary and that relevant innovation emerges from the interaction between scientists, farmers, traders and companies. The new role of extension is therefore involvement of major stakeholders in innovation or a wholistic system management for optimal effect.

These new approaches of extension require a new definition of extension. The new definition of extension service for the new approaches in the new millennium is given by Knipscheer, *et al* (2001) as a knowledge management organization, the purpose of which is to introduce change for the benefit of its clients. This implies getting the right information to the right people at the right time in a user-friendly manner. Therefore, the extensive service should have intellectual capital (understanding, insights, technologies as well as skills, expertise, organization ability to meet market requirements and customer capital or goodwill); it should be a learning organization to the core; it should create, store and retrieve, distribute and apply knowledge; and it should be based on partnerships and collaboration among stakeholders.

In this regard, the specific roles of an extension organization are (Knipscheer, *et al*, 2001):

- Dialogue among stakeholders in agricultural extension
- Development of a consensus on the vision and goals of the extension system and setting up priorities for action.
- Analysis of the training needs of extension staff in terms of critical knowledge, skills, and attitude.
- Encouraging and assisting agricultural colleges and universities to revise their curricula to make them more responsive to the changing job market.
- Forging a strong network among institutions and agencies to benefit from the diverse talents, resources, experiences and perspectives
- Ability to cope with challenges
- Ability to identify and convene stakeholders.

These new extension service roles imply new roles for the extension agents. In this regard, they are to be managers of change; facilitators; information seekers; and option providers.

In general, extension organizations have two essential roles to play in the 21st century (Röling, 1995):

1. Facilitation of group processes (in small groups of clients). Such facilitation has not been considered as the task of conventional technical extension, but in the changing role of extension, facilitation seems to be a key activity
2. Knowledge management to achieve synergy and enhance performance in the networks of actors. Conflict may be inevitable among stakeholders with diverse views and interests. Therefore, an important role for

extension is to achieve cooperation, conflict resolution and harmonization between the various players.

The processes of facilitation and knowledge management involve bringing out to the open, the diverse views and interests of the actors involved, negotiation and accommodation to create shared objectives, common appreciation of problems and mutual independence, joint learning about local systems and contexts, brainstorming and finding solutions to develop alternatives, and shared monitoring systems to allow joint learning (Röling, 1995). In this regard, the envisaged role expansion will include more emphasis on social goals of poverty alleviation through facilitation of gainful employment or alternative livelihoods for the poor, improved nutrition (eg. high protein maize) of the rural families and ensuring food security at all levels. Extension will also take on the role of conserving the environment.

The Challenges of Agricultural Extension in the 21st Century

The role of agricultural extension in the 21st century poses numerous challenges which should be faced squarely in order to successfully perform the role. Some of these challenges are hereby highlighted.

Extension methodologies

Sustainability or responsible management of natural resources depends upon community action. Therefore, research and extension should adequately take natural resource management into account and generate effective extension methodologies for motivating farmers for community action and develop and disseminate appropriate technologies for the management of community resources as well as individual farms.

Training extension personnel

A change in extension approaches implies retraining and new approaches to training of extension personnel. Sustainable agricultural development and farmer-led approaches would require extension personnel to have a sound knowledge of farming systems and the physical and socio-economic environment in order to be able to adapt technical advice to local environments. The extension personnel must have analytical skills to be able to help farmers identify production problems and the potential for improvement. They must be able to work closely with groups and communities and act effectively as intermediaries between groups and government institutions. They must have good training in communication skills (with groups and with individuals) and they should know very well the learning and teaching methods which are necessary for sustainable extension. In this case their role would be to facilitate learning and not to import information only. That is, they should have the ability to work in a participatory mode of extension rather than a linear, technology transfer mode. In short, the training needs required are skills in science, technology, managerial, communication and human-relations for sustainable agricultural and rural development.

Extension education

Extension education is generally weak, bogged down by inadequate funding and debilitated by outdated and irrelevant curricula. Other problems facing extension education include lack of communication with the employers of university graduates, poor practical skills, and high unemployment of university graduates (Magure, 2001). As such, the universities are not leading in upgrading the skills of research and extension practitioners and in preparing capable professional agriculturalists for the future.

In facing up to this challenge, SG 2000 has developed an innovative extension education program for mid-career extension workers in order to 1) provide opportunity for mid-career extension workers for leadership positions, and 2) link extension curricula more closely to the real world of farmers and help university facilities to broaden their perspectives by frequent contact with the rapid change taking place in rural areas. The program which has taken off in four African countries, is to start in 2002 in Nigeria.

Control and accountability

Extension services have been considered as a social service and therefore paid for by the government. But future trend of policy of decentralization and privatization and dwindling public financial support would mean privatizing some aspects of extension and introducing partial cost recovery from farmers. Then, paying for the services would give farmers some control over the providers of the services and make extension workers more accountable to the farmers. But then, government would continue to finance extension in strictly social/communal areas such as environmental protection and management and resource-poor households and the disadvantaged groups. Hence, the main issues for the future are identification of areas of coordination between NGOs, private sector and the public extension/research organizations, and deciding on the mechanism for such coordination. Thus, dialogue between stakeholders would be imperative.

Equity and targeting

By design and/or by chance, extension programs have favoured the wealthier, more educated, more influential farmers and male farmers. This has widened the gap between these and the poor, disadvantaged and female farmers. In future, extension should target at the resource-poor households, marginalized, women farmers, and training of female extensionists and low-cost, low-risk technology.

Role of Farmers' Organizations

Past extension work was focused on individual farmers. Now the many potential advantages of farmers' organizations for extension has been better realized. These organizations offer the opportunity for greater efficiency, effectiveness and equity of provision and access. They can serve as a means by which farmers can pay for services, become actively involved in the planning and management of extension, and act as a voice for their members in bringing services which meet their needs (Garforth and Harford, 1997).

Effective use of mass media

Mass media have been used based on a technology transfer principle. In future, a participatory approach to the identification of program content would ensure that the mass media programs are based on expressed information needs of farmers. Also with the increasing globalization of information, farmers should have access to various channels of information, and mass media would be appropriate for this task. Thus, extension services delivery must face the challenge of globalization impact.

CONCLUSION

Agricultural extension in Nigeria in the 20th century was a highly centralized government organization characterized by focus on technology delivery, emphasis on high-input technologies, neglect of small mixed farming systems, inappropriate technology for subsistence farmers and poor linkage with NGOs.

The wind of change moved extension to increasing attention on natural resource management, sustainability and group and community involvement in extension, inclusion of non-government extension providers, farmers groups and interative, experiential and responsive learning. The forces behind the change include liberalization, democratic governance, decentralization, globalization and cost factor.

Accordingly, the role of extension has been undergoing gradual change. In the new millennium, there will be a clear reversal of the role of extension from technology delivery approach of the immediate past century to facilitation of change and knowledge management in the rural areas leading ultimately to decentralized, participatory, collaborative, farmer-centred, farmer-led and farmer-controlled extension and rural development programs including "Maize for Better Nutrition" program.

However, this process of change will bring about new challenges to extension. The challenges to face up would include change of extensions, methodologies, responsive extension training and education in colleges and universities, user control and extension accountability, equity consideration, and effective use of mass media.

REFERENCES

Axinn, George H. (1997). "Challenges to agricultural extension in the twenty-first-century". In: Vanessa Scarborough *et al* (eds). Farmer-led Extension: Concepts and Practices. London: Intermediate Technology Publications Pp. 13-22.

Garforth, C. and **N. Har**ford (1997). "Extension Experience in Agriculture and Natural Resource Management in the 1980s and 1990s" In: V. Sarborough, *et al* (eds.) Farmer-led Extension: Concepts and Practices. London: Intermediate Technology Publications Ltd, Pp. 23-33.

Knipscheer, Henk C., M.M. Zinnah and J.**K. Mutimba** (2001). Addressing the Challenges of Extension Services Delivery in Sub-Saharan Africa Through Responsive Extension Education. Presented during the Workshop on Africa Food Security in a Changing Environment: Sharing Good Practices and Experiences, Kampala, Uganda-June 6th-9th. Sponsored by Sasakawa Africa Association.

Magure, Charles J. (2001). "Agricultural Education in Africa: Managing Charge". In: Joseph A. Kwarteng (ed.) Extension Education: Reshaping African Universities and Colleges for the 21st Century. Geneva: Centre for Applied Studies in International Negotiations.

Pretty, J.N. (1995). "The Changing Role of Agricultural Extension" In: Agricultural Extension in Africa: Proceedings of an International Workshop, Yaoundé, Cameroon. Wageningen: Technical Centre for Agricultural and Rural Co-operation.

MAIZE AS A POTENTIAL SOURCE OF INCOME AND FOREIGN EXCHANGE EARNING IN NIGERIA

S.A. Ingawa*

INTRODUCTION

Nigeria is endowed with a large expanse of arable land, a large population of unemployed and underemployed labour force, a veritable stock of human capital in the research institutions, universities and colleges of technology. In spite of the vast agricultural potential, the leading source of income and foreign exchange in the country is the petroleum sector. This has subjected the economy to the vagaries associated with fluctuation in the world prices of oil. The security implications and disadvantages for a growing economy cannot be overemphasized. There is need to diversify the source of income and foreign exchange to the economy. With appropriate resource reallocation measures in place and policy actions geared to increased production of certain agricultural commodities, the income and the foreign exchange earning of the country will be enlarged. This paper assesses the potential of maize as a veritable source of income and foreign exchange earning for Nigeria.

Maize (*Zea mays* L.) is the third largest crop grown in the world. It could be used in more than 2000 forms. It is the most diversified food, feed and industrial crop (CIMMYT, 1994). It is a very popular stable food and industrial cash crop in Nigeria.

The environmental conditions in the rain forest and Savannah zone of the country are particularly favourable for the production of maize. Ingawa)1990), noted that maize fits well into the farming systems of Nigerian small farmers. Maize matures in about 90-120 days. With current pace of the development of dry season (irrigation) farming in the country, maize could be cropped on a piece of land three times in year. As an incentive to encourage the production of maize in the country the Federal Government of Nigeria (FGN) placed maize on the import prohibition list in 1996 and 1997.

Population pressure on land and the land tenure systems have made it appreciably difficult to increase the area under maize cultivation over time. According to Maziya-Dixon (1999), increases the production of maize are expected to come from yield increases since little additional land can be bought under cultivation.

Proposition

The basis for exporting a commodity is determined by the production possibility frontier schedule and the international terms of trade. If the world price of maize is high relative to the domestic price then the terms of trade is favourable for exporting maize and if it is possible to reallocate domestic resources and / or improve the productive power through technological advancement to produce marketable surplus of maize, then the exportation of the commodity can be sustained.

Objectives

The objective of this paper is to determine weather maize could be a major potential source of income and foreign exchange earner for Nigeria. The derived objectives include:

- Comparative analysis of the world and domestic prices of maize to determine weather the terms of trade favours exportation of maize;
- Estimate the growth rate and average annual rate of change of land area cultivated to maize in the country to determine weather the rates are significantly positive to guarantee the existence of a marketable surplus;
- Estimate the growth rate and average annual rate of change in the yield (productivity) in the country to determine weather the rates are significantly positive to allow for the generation of marketable surplus.

Methodology

The data used in this paper are secondary, time series data obtained from the Project Coordinating Unit (PCU) which has the mandate to collect and consolidate agricultural data in the country. The growth parameters are estimated using the Ordinary Least Square (OLS) regression technique. The technology situation about maize production in the country is assessed through the review of available literature on the subject. Result of the empirical analysis and literature review are presented, discussed and conclusions together with recommendations made.

Comparative Analysis of the World and Domestic Prices of Maize

In order to determine the profitability of exporting maize from Nigeria the export parity price for the commodity is computed and the Free On Board (FOB) price is compared with FOB price of maize quoted for any other country exporting maize. If local FOB price is lower than the foreign one it implies that the term of trade favours the exportation of maize i.e. it is profitable to export maize. The Development Project Group of the World Bank estimated year 2000 FOB price of a metric tonne of maize at Gulf of Mexico, United States of America at $95.00. The computation of year 2000 FOB price of maize at Apapa port in Lagos, Nigeria is illustrated in table 1.

Table 1: Estimation of Year 2000 FOB Price of Maize

	Description about a metric tonne of maize	Value
1.	Whole sale price (Lagos)	22050
2.	Local transport to Apapa port	1000
3.	port changes including: taxes storage, loading fumigation, tariffs and agent fees (5%).	1102.5
4.	FOB (Lagos)	N24152.5
5.	Dollar equivalent (exchange rate $1.0 = N112.0)	$215.7

The ratio of FOB (US Gulf) to FOB (Apapa) is 0.44 (95/215.7) which is less than unity. It implies that the current terms of trade does not favour the exportation of maize from Nigeria to the US Gulf. This finding may explain the fact that the Federal Government of Nigeria (FGN) placed maize on the export prohibition list since 1997. The ban seemed unnecessary, anyway, since the local price is not competitive. Is the term of trade reversible? Yes. The term of trade for maize is reversible by pushing out the production possibility frontier to produce more output and bring down the domestic price of maize. How could this be done? There are two possible ways of increasing output: the first way to increase the land area under the cultivation of maize: and the second one is by increasing the productivity per unit area land under maize production. On exploring the approach, it is pertinent to ask weather current inter-temporal changes in the annual acreage under maize cultivation indicates that given sufficient time, will the desired output level be attained? To answer this question, this paper estimated the growth rate and annual rate of change of the area cultivated to maize in the country to determine whether the rate is significantly positive such that given sufficient time will generate the desired marketable surplus.

Regression Result for Land Area Under Maize Cultivation in Nigeria

The estimated growth rate and annual rate of change of land under maize cultivation in Nigeria is presented in table 2.

Table 2: estimated Growth Rate and Annual Rate of Change of Land Area Under Maize Cultivation

Parameters of the growth equation

Land area	=	3136.9	$(1+0.005)^t$
Std Error		0.054	0.009
T-statistic		150.1	0.55

R^2 = 0.32; Std error of Estimate = 0.095; F statistic = 0.29

parameters of annual rate of change equation

Land area	=	3157.3 +	14.34t
Std Error		176.3	14.34
T-statistic		17.9	0.48

R^2 = 0.025; Std error of Estimate = 312.56; F-statistic = 0.23

The t-statistic for the estimate coefficients of time in table 2 are less than 1.96. This indicates that using two-tailed test at 95% level of confidence, the estimate parameter with respect to time are not significantly different from zero. The F-statistic in table 2 are less than 1. This indicates poor fitness of equation I.e. that time alone is not sufficient explanatory variable of the inter-temporal changes in the cultivated land area. The R^2 are not greater than 0.32. This indicates that time alone, as an explanatory variable could not explain more than 32% of inter-temporal changes in cultivated land area.

The t-statistics in the equation indicated that estimated growth rate and annual rate of change of the area cultivated to maize are not statistically different from zero: that is, that land area under maize cultivation is stagnating over time.

It is evident from this analysis that the land under area maize cultivation does not grow or increase appreciably with time. This implies that the production of exportation surplus of maize in the country may not be achieved through the increment of cultivated land area. This view is supported by a host scholars including Famoriyo et al (1981), Busie Maziya-Doxon (1999), Abalu et al (1981), Nwagbo (1981) and Oredipe (1998),

Famoriyo et al (1981) noted that the prospect of increasing agricultural production by land expansion is possible in areas where cultivable land is still available. This happen in Nigeria between 1960-71 when most of the increases in food took place by expansion of the acreages of maize, sorghum, rice, cowpea, yam and cassava. But this option is not open particularly in major maize producing areas of Kaduna, Katsina, Bauchi Gombe and Kano States.

Abalu et al (1981) observed that there is rising difficulty in acquiring land for agriculture and that the fragmented holdings of Nigeria farmers are not viable for far-reaching technological changes. Nwagbo (1981) and Oredipe (1998), concluded that the way forward is increasing land productivity through acquisition of improved technology and that not much incremental output or income is possible without change in the technological frontier of maize production in Nigeria.

In exploring the second approach, the question whether current inter-temporal changes in the productivity of maize in Nigeria indicates that, given sufficient time, will the desired output level be attained? To answer this question, this paper estimated the growth rate and the annual rate of change of the yield (productivity) per hectare of maize in the country to determine whether the rate is significantly positive such that given sufficient time the desired marketable surplus will be generated.

The t-statistic for the estimated coefficients of time in table 3 are greater than 1.96. This indicates that using two-tailed test at 95% level of confidence, the estimated parameters with respect to time are significantly greater than zero. The F-statistic in table 3 are greater than 1. This indicates good fitness of the equations I.e. that time alone explained a large proportion of the inter-temporal changes in yield of maize. The R^2 are 0.5. This indicates that time alone as an explanatory variable explained up to 50% of inter-temporal changes in the yield of maize. The t-statistic for the estimated coefficients of time in the equations indication that the estimated growth rate of the area cultivated to maize are statistically greater than zero. Specially, it indicates that the yield of maize was growing overtime at a rate 2% and the average annual rate of change in yield of maize is positive I.e. 30.23 thousand metric tons annum.

REGRESSION RESULTS FOR MAIZE YIELD

The estimated growth rate and average annual of change of yield of maize in Nigeria is presented in table 3.

Table 3: Estimated Growth Rate and Annual Rate of change of Yield of Maize

Parameter of the growth equation				
Maize Yield	=	1312.9		(1+0.022)t
Std Error		0.046		0.008
T-statistic		155.9		2.83
R2 = 0.5; Std error of Estimated = 0.08; F-statistic = 7.98				
Parameter of annual rate of change equation				
Land area	=	1323.03	+	30.23 t
Std Error		63.71		10.77
T-statistic		20.8		2.8
R2 = 0.5; Std error Estimate = 112.9; F-statistic = 7.9				

This positive growth rate may be attributed to the extension efforts of the Agricultural development projects (ADPs) nationwide. This growth rate however is not satisfactory towards achieving the expected output for domestic consumption and exports. According to the Central Bank of Nigeria (CBN), (1996) and the National Rolling Plan (1992-95), the agricultural sector is expected to attain an annual real growth rate of about 7.2%

According to Abalu et al (1981), under traditional production technology the yield rate of maize is estimated at 1.046MT. The national estimated mean yield per hectare is 1.323MT. However, the estimated mean yield for farmers adopting improved technology is 3.000 Mt/Ha and at Research Stations a mean a yield of 7.840 Mt/Ha has been attained. It is gratifying to note that some Sasakawa Global 2000 participating farmers have also now been shown to have achieved the quoted research station yield of 8 tons per hectare.

It is evident from this analysis that the productivity of maize in the country grows (increase) with time. The current rate of growth is too low to be relied upon for the production of exportable surplus of maize in Nigeria. There is therefore the need to rapidly increase the productivity of maize per unit area in order to obtain exportable surplus.

This view is supported by Awoyemi (1981), abalu, Famoriyo and Abdullahi (1980), Ingawa (1999) and Oredipe (1998). These authors observed that the problems militating against Nigerian agriculture are:

- Technological gap I.e little application of modern technology, poor management practices by farmers, inefficient marketing system, inadequate financial resource, low level of capital investment, high wage rate of farm labour, large incidence of diseases and pests and ineffective government policies;
- Known biological discovery which could transform maize production in the country are not being extended to farmers and of the innovations do not go beyond the gates of the universities and research institutions;
- Farmers tools and mode of operation have not changed for generations; and
- Young and able-bodied men have deserted the farm, leaving it to the aged and women.

SUMMARY AND CONCLUSIONS

Currently, the terms of trade does not favour the exportation of maize from Nigeria. This may explain why in 1997 the Federal Government of Nigeria (FGN) placed maize on the export prohibition list. However, the terms of trade for maize is reversible by pushing out the production possibility frontier to produce exportable surplus output and bring down the domestic price of maize. The land area under maize cultivation does not grow or increase appreciably with time. This implies that the production of exportation surplus of maize may not be achieved through the increment of cultivated land area.

The productivity of maize is found to increase with time in Nigeria. However, the current rate of growth is too slow to be relied upon for the production of exportable surplus of maize. There is still a wide room for increasing the productivity of maize through adoption of improved production technologies by farmers. Efforts to produce marketable surplus that will reverse the terms of trade of maize to favour the exportation of grain by Nigeria will be geared at increasing the productivity per hectare of maize.

RECOMMENDATIONS

To produce an exportable surplus of maize should be taken by the various tiers of government. These policies will be directed mainly at:

- Revamping the agricultural extension system of agricultural development projects to enable the dissemination of modern technology and improved management practices to maize farmers;
- Improving the support to agricultural research system to enable the generation of appropriate improved technology and practices;
- Strengthening the linkage between the research, extension system (ADPs / Farmers) and the private sectors;
- Encouraging farmers especially the youths to take up the maize farming as an attractive and profitable enterprise.
- Export prohibition may be counter productive to Nigerian agriculture.
- There is need for policy stability with respect to agriculture.
- Budgetary allocation to the sector needs to be substantially raised.
- Put the farmers in drivers seat and empower them to master their productivity and marketing circumstances.

Thanks to the organizers, SG2000, IAR / ABU Zaria and the cooperating ADPs for this opportunity to discuss issues with regard to our wonder crop MAIZE.

Thank you all.

REFERENCES

Abalu G.O.I. Et al (1981), *Production Problems in Nigerian Agriculture,* A Paper presented in a Seminar on Agricultural Credit and Finance in Nigeria: Problems and Prospects Organized by the Central of Nigeria, April 27-30.

Awoyemi O. (1981), *Problems Of Agriculture In Nigeria:* A Paper presented in a seminar on Agricultural Credit and Finance in Nigeria: Problems and Prospects Organized by the Central Bank of Nigeria, April 27-30.

CBN Various *Publications Annual Report And Statement Of Account,* Central Bank O Nigeria.

CIMMYT (!994), *CIMMY 1993 / 94 World Maize Facts and Trends.* Maize Seed Industries, Mexico DF CIMMYT.

Development Projects Group (October 1999), *Global Commodity Prices: a comprehensive review and price forecast,* IBRD, The World Bank, 1818 H Street N.W. Washington DC. 20433, USA.

Famoriyo, S. (1979), *Land Tenure And Agricultural development In Nigeria*. Ibadan University Press. Ibadan.

Ingawa, S.A. (1999), *Socio-Economic Considerations in Maize Production In Nigeria.* A paper presented at Maize Production Workshop Organized by SG2000, IAR / FMARD / ADPs; Ahmadu Bello University, 22nd –24th July 1999, pp. 71-75..

Maziya-Dixon, B. (1999) Maize As A Food Source And Industrial Material Processes, Products And Uses. International Institute Of Tropical Agricultural, Ibadan, Nigeria.

Nwagbo E.C. Famoriyo S. (1981), *Problems of Agricultural Finance in Nigeria.* A Paper presented in a Seminar on Agricultural Credit and Finance in Nigeria: Problems and Prospects Organized by the Central Bank of Nigeria, April 27-30.

Oredipo A.A. (1998), *An Analysis Of Efficiency and Productivity Gaps Among Farmers Adopting Improved Maize Technology In Ogun State, Nigeria*. Unpublished Ph.D. Thesis, Department Of Agricultural Economics, University Of Ibadan, Nigeria.

Oyetoye, E.T.O. (1980), *An Economic Assessment Of Selected Government Agricultural Projects In Western Nigeria.* Unpublished Ph.D. Thesis, Department Of Agricultural Economics, University Of Leeds.

Appendix 1: Summary of the Regression Results

Dependent Variables	Const.	SE-Const	t–Const	Coeff	SE–Coeff	t–Coeff	R—square	SE–Estim.	F-Stat.
Log AREA	8.05	0.05	150.1	0.005	0.009	0.55	0.32	0.1	0.29
Log OUTPUT	8.33	0.1	86.6	0.026	0.016	1.65	0.23	0.17	2.73
Log YIELD	7.18	0.05	155.9	0.022	0.008	2.83	0.47	0.08	7.98
AREA	3157.3	176.3	17.9	14.34	29.8	0.48	0.03	312.56	0.23
OUTPUT	4242.8	450.8	9.4	109.11	76.19	1.43	0.19	799.12	2.05
YIELD	1323	63.7	20.8	30.33	10.77	2.81	0.47	112.95	7.88

Appendix 2: Time series Data Used in the Paper

YEAR	OUTPUT In '000 Mt.	AREA In '000 Ha.	YIELD In Mt/Ha.	PRICE Kobo / Kg.
1990	3163.70	2802.86	1128.74	
1991	3913.82	2904.40	1347.55	
1992	4452.44	3195.85	1393.19	
1993	4861.51	3295.87	1475.03	648.00
1994	5896.18	3671.38	1605.98	713.00
1995	6145.87	3792.03	1620.73	1448.00
1996	4667.78	3253.37	1434.75	1756.00
1997	4811.22	3144.26	1530.00	2325.00
1998	5305.53	3253.10	1630.00	2829.00
1999	5021.71	3271.17	1540.00	1919.00
2000	4431.68	2934.88	1510.00	2205.00

Source: Time Series Database: Monitoring and Evaluation Programme, PCU, Sheda, FCT.

APPROACHES TO IMPROVING MAIZE TECHNOLOGY DELIVERY SYSTEMS IN NIGERIA

A.M. Falaki, M.A. Hussaini and S. Miko*

INTRODUCTION

Maize is one of the important food and industrial crops in Nigeria. Worldwide, wheat, maize, and rice are produced in greater quantities than other crops. Among these crop, maize has the highest average yield hectare. Maize is good source of energy for human and animal and it is high-yielding, easy to process and readily digested (Okoruwa and Kling, 1996).

As at 1997, the world production of maize stood at 580 million tonnes, with Nigeria producing about 6.2 million tonnes of a mere 1.1% of the world's output (FAO, 1997). Yet maize is the most important cereal crop grown in Nigeria; the area of its production stretching from the coast in the to the savanna areas in the North. It is a principal component of the different cropping systems in all the parts of the country .Maize production in the country was until early 1970s confined to the forest zone. In the savanna, maize production has since been transformed from the status of a minor crop by being grown around the homestead to a major commercial grain crop, competing with sorghum and millet as a strategic crop in the grain economy of the nation (Elemo, 1993). Infact, about 70% of the maize in Nigeria is produced in the savanna zone.

Unfortunately, the spread of the modern maize production technologies in most of these maize areas, especially the Northern Guinea savanna, which provides the greatest potential, has been much less dramatic. In most areas, yields have been below 2t/ha, and infact, Nigeria's average yield is 1.36/ha which is about 1/3 of the World's average of 4.13/ha (FAO,1997). Higher yield tends to be associated with the large-scale farmers who grow maize on commercial scale and the lowest yields are common with the small-scale farming communities, who grow maize mostly for subsistence but, are often forced to sell the grains soon after the harvest to meet family needs.

The key point is that significant maize productivity gains are possible for all classes of farmers, provided they have access to the technological components.

The role of Extension in Maize Technology delivery:

For a long time, extension was the step which followed after research. This seems logical: research finds a solution to a certain agricultural problem, and must find a way to transfer this solution to farmers through extension who then put the new technology into practice.

Nowadays, it is recognized that this one-way flow of information, ie from research through extension to the farmers is <u>insufficient</u>. Extension interaction between the different component is essential to obtain satisfactory results. In this, the extension services play an essential role: on one hand by taking

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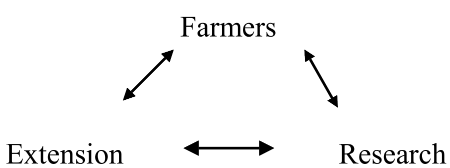
information from one party to another (ie from research to farmers), on the other hand by effecting the necessary feed-back between the two parties. In this sense, extension is no longer the following step after research, but can take place simultaneously with, or even prior to it.

The arrows going left represent the process of "problem definition" the arrows going to the right depict the process of "problem solution" (schoubroeck, et. al., 1989).

Most recently, the approach has shifted to a more participatory approach as illustrated by the technology triangle (Schulz, 2000)



The principle is to engage farmers and resource persons from different institutional backgrounds in interactive learning and action.

Improving Maize Technology Delivery Systems

Maize technology delivery systems comprise public and private institutions and bodies that develop and supply new varieties, improved crop management practices, and production practices to farmers. These bodies include research organizations; extension and technical advisory services; suppliers of improved seed, fertilizer, crop protection chemicals, and farm machinery; and agricultural lenders. (Dowswell et al., 1996)

The development of maize technology delivery systems is strongly influenced by government policies. In industrialized countries, the private sector a major role in the delivery of improved maize technologies to farmers. These private businesses have benefited greatly from publicly funded maize research and development programs. Over time, a well-integrated and highly effective public-private maize research and development system has evolved, one that is capable of generating and transferring to farmers a continuing stream of productivity-enhancing maize technologies.

However, in Nigeria (typical of a developing nation), the organizations that make up the national maize technology delivery systems are primarily within the sector. Although public institutions have had success in developing maize technologies, government organizations responsible for delivering improved technology to farmers generally have not functioned well. As a consequence, maize research pipelines are full of productivity-enhancing technological components that generally fail to get beyond the boundaries of experiment stations. The efficiency of maize technology delivery systems can be gauged from the gap that exists between farmers' actual yields and optimum economic yields observed non-farm maize technology validation trials (table 1). Nigeria happens to have one of the lowest technical efficiencies (40%) among the major maize growing countries in the world. A national maize technology delivery system whose technical efficiency is below 50% has serious flaws. Low technical efficiency scores are generally caused by some combination of ill-functioning supply systems for seed and fertilizer, farmers' poor knowledge of recommended crop management practices, discriminatory price policies, and farmers' lack of sufficient capital to employ the recommended inputs and crop management practices (Byerlee, 1987).

Raising the technical efficiency above 70% is probably only possible when we have a well developed market economy and highly developed rural and agricultural infrastructure. Thus, farmers will produce maize strictly on a commercial basis. They must then have access to current technical information, possess high level skills in crop management, and be able to operate close to the margin of economic efficiency.

Input Supply Strategies

Since availability of improved farm input is a pre-requisite to intensive agriculture, different policies and programmes have to be put in place to promote efficiency in the production, procurement and distribution of agricultural inputs. The challenge facing government is to formulate policies that promote the development of effective input supply systems. In the past, governments have opted to develop publicly funded input supply organizations such as Kano State Agriculture Supply Company (KASCO) in Kano state and Farmers Supply Company (FASCOM) in Kaduna State. With many failure, the trend now is towards shifting input supply functions to the private sector. The development of viable and dynamic private organizations will not however, come overnight nor very easily. The high cost of rural transportation and the difficulty of reaching small-scale farmers with the needed inputs themselves, in a timely fashion argue strongly for some continued public-sector developmental support in building effective agricultural input supply systems. No private business will succeed where basic infrastructure are not available, social amenities are not affordable, security of investment is not guaranteed, and there is lack of consistency and stability of policies.

An effective maize technology delivery system in Nigeria will therefore require a more serious participation of government. Although there is no specific policy for maize (Edache, 1999) the National policy of Agriculture would have to be strengthened to ensure the supply of agricultural inputs at affordable and sustainable manner. If the industrialized nation of Western Europe and North America will continue to heavily subsidize their Agriculture (world Bank, 1989) there is no reason why the Nigerian government should not take measure in the same direction.

The importance of seed-fertilizer interactions should not be over looked. Infact, no farmer will ever plant maize on his farm if he/she is not assured of fertilizer, especially with the use of improved germplasm. Farmers that tends to plant improved maize germplasm but apply very little fertilizer, can only realize productivity grains through greater use of fertilizers. Similarly, farmers that use fairly high levels of fertilizer but little improved seed can raise yields through greater use of improved varieties.

Extension Approaches

Extension, as mentioned earlier, is an integral part of an effective maize technology delivery system. In the past, the front-line extension worker was engage in broad activities including community development and non-farm aspect of agricultural development such as public work supervision, assistance in electoral registration, adult literacy campaigns, public health campaigns, youth club management, etc. it therefore became clear that they could not be effective in supporting agriculture if they are the call of several ministries parastatals. Moreso, most extension field staff were poorly trained and that farmers often lack confidence in their technical and diagnostic abilities. Thus, upgrading the technical knowledge of extension officers in-service training courses and meetings is extremely important. To address these problems and many other deficiencies of the previous approaches, the Training and Visit (T&V) extension system was introduced in 1986 and in 1992 the Unified T&V extension concept was introduced. Under this system, all extension activities covering crops, livestock, fishery, agro-forestry and women in agriculture are under one unit, that is, the ADPs. The T&V seeks to strengthen three critical needs: the need to make extension staff into specialists in production technology, the need for sustained field efforts, and the need for regular instructions (Dowswell et al., 1996). However, experts criticise the T&V, contending that most recommended technologies involved the use of inputs such as fertilizers, which must be closely linked to inputs availability. This led to the introduction of REFILS, which is a recent concept, and encompasses research, extension, inputs agencies and farmers.

As earlier observed the T&V system does not encourage the involvement of the extension agents in the supply of production inputs or marketing of produce. Certainly, this is a big minus on the system. Efforts must be intensified to link maize farmers with the appropriate input agencies. Government as a matter of policy must continue to fund research while at the same time providing opportunities to farmers to effectively utilize the products of the research through the setting up and support for the input delivery agencies. But most importantly for extension to succeed, there has to be a deliberate effort to motivate the staff i.e. good remuneration, transportation, training, promotion etc.

Maize Technology Demonstration

Successful maize production campaign can have a positive training and motivational impact on extension officer. The ability to provide farmers with the to radically improve maize productivity is a powerful morale booster for the extension service. With the production test plot as the common ground between the extension officer and the farmers, their relationship is strengthened. Maize production campaigns can accelerate the adoption of improved technology by farmers who use low-yielding production systems. They are most successful when they involved cooperation among research, extension, seed production, fertilizer supply, farm machinery, and agricultural credit organizations.

The trial should be large enough to represent a legitimate test in the eye of the cooperating farmers. The demonstration plot should be at least 0.2 hectare and preferably 0.4 to 0.5 hectare to have a strong psychological impact on the farmer. The farmer should grow a companion plot 0.4 to 0.5 ha along side-also using traditional technology for the purpose of comparison.

Farmers' Roles in Technology Diffusion

Farmer-managed field demonstration plots are the heart of an effective maize technology transfer campaign. These practical lessons are designed to let farmers test, evaluation, and possibly adapt the recommended crop technologies. Once the economic superiority of the recommended crop maize technologies has been verified in 30 to 40 test plots, it should be vigorously promoted through hundreds and then thousands, of farmer-managed demonstration plots. Usually, the demonstration program in each village should last 2 to 3 years. In the first year, a few demonstration plots (about 10) should be established. Each plot will provide training for the participating farmer as well as "cluster) of neighbouring farmers. In the second and third years, the number of demonstration plots can be expanded four-or-five-fold (Dowswell et. Al., 1996).

The success of any maize technology program will require the sustenance of input supply. The extension service must therefore unsure that the farmer who takes part in the maize demonstration and testing program have access to improved seed, fertilizer, and other key inputs of the recommended production technology. For the small-scale low income farmers, it may be necessary to supply these inputs on loan, especially during the first year of field demonstration in a village.

Farmer Training

Using the 'cluster' system of participating farmers, the most intensive training in the recommended maize production technologies occurs during the first year. Farmer trainings should mirror the training sessions for the extension agent; pre-planting, planting and initial fertilizer dose, weed control and second fertilizer dose, flowering and crop assessment, harvest and yield calculations. The importance of providing proper farmer training, especially during the year of demonstrations in a village, cannot be over-emphasized. It is expected that the first-year participants will pay a teaching and technology diffusion role with new farmers who join in the program in the second and third years. Field days should be organized for villagers to see the results of the demonstration plots and to discuss the factors responsible for the yields achieved.

Involving Policy Makers

A dynamic on-farm maize demonstration program can have important impacts beyond teaching farmers about improved methods of maize crop management. It must also serve to influence government policy makers and private entrepreneurs to take decisions that encourage farmers to try new practices. It is therefore vital that decision makers visit the demonstration plots to see first-hand, the superiority of the production recommendations. The best time to invite influential people to visit the plots is during the field days organized towards the end of the crop cycle.

The Role of Private-Sector in Technology Delivery

The role of private-sector in technology delivery has been discussed partly in the earlier part of the paper. However, it is necessary to emphasize that the private-sector has no better opportunity than now when government policies (though genuinely resisted) are gradually moving towards privatisations must undertake the delivery of improved technologies and research products developed by public-sector organizations. Seed production and distribution of improved varieties, and hybrids fertilizer distribution, farm machinery services, and crop marketing are all prime candidates for private activity. Infact, it is even time for the private sector to begin to participate in research and development activities rather than waiting for the public-sector to provide. With the commercialisation of farming activity (maize inclusive) it may be necessary to encourage private sector involvement in extension services even if not in a form of consultancy service but the marketing of their products. But to get private sector involvement effectively, government has to provide the enabling environment through the provision of infrastructure and the right policies.

Maize Technology Delivery System-SG2000 Approach

The SG2000 approach entails the conduct of pre-season training of trainers (TOT) for selected Extension Agents (EAs) and some enlightened farmers who are to participate in the Management Training Plot (MTP) establishing during the proceeding season. The EAs and farmers thereafter return to their states to conduct preseason training for selected farmers who will participate in the MTP establishment.

One of the cardinal issue in the approach is the timely procurement of good quality inputs (seed, fertilizer and agrochemicals) from reliable sources. Farm (0.25 –0.50 ha) targeted for MTP establishment are clearly measured (to ensure their sizes) and demarcated with pegs before the onset of rains. The extension agents pay regular visits to farmers during the critical stages of crop establishment in order to ensure good land preparation and maintenance of 133 ridges / hectare at a spacing of 75 cm between ridges and 25 cm within to attain a population of 53, 300 plants/hectare.

Compound fertilizer (NPK) is applied a week after planting in a hole about 12 cm away from the crop stand. When using NPK (20-10-10), 9 bags (450kg)/hectare are applied. The second application of N in form of Urea (43% N) is undertaken when the crop is at Knee height. Weeding are generally done manually with the second weeding coinciding with the second fertilizer application and remoulding of ridges.

During the season, more visits are undertaken by the EAs, Zonal and State Coordinators to address any possible field problems (pest and disease incidences, soil problems etc).

At the peak of the season, field days (major and minor) are conducted at MTPs sites. During the field days farmers from neighbouring villages, scientists, input agencies and policy makers are invited to participate in the field days where each farmers explains what he did to obtain good crop of maize. Each field day serves as an avenue for farmer-to-farmer transfer of technology and thereafter farmers show interest to participate in the programme during the coming season.

The aspect of record keeping are strictly adhered to. All records related to cost production are kept for each farmers. Other records including village and farmer name, variety planted, date of planting, type (s) of fertilizer used, dates of first and second application, problems encountered etc. are collated, entered into computer data sheets and submitted to the office.

At physiological maturity stage, farmers are advised to bend the cobs downwards in order to hasten drying, prevent bird damages and avoid rainwater getting into the cobs to cause moulding. At harvest, EAs move round the MTPs with weighing scale to record and determine the exact yield obtained from each MTP. Farmers are graduated after conduct of successful MTPs to allow new ones have access to the technology.

CONCLUSION

Maize has the greatest potential of success among all the major cereals commonly cultivated in Nigeria. The yield per unit area far exceeds any other cereal crop and is of great significance as a food and feed for livestock and poultry and also for several industrial purposes.

All the research efforts put in place so far to come up with appropriate technologies in maize cultivation/production will lead to only marginal yield increases unless they are backed up with appropriate technology transfer mechanisms. The key among the component technologies are improved germplasm and fertilizer. Infact, maize requires much more fertilization than the traditional cereals (sorghum and millet) to produce a worthwhile yield.

This means an effective research-extension-farmer-linkage system has to be developed in clode association with input supply agencies from both public and private organizations and supported by credit/lending agents.

REFERENCES

Byerlee, D. 1987. Maintaining momentu in post -green revolution agriculture. A micro-level perspective from Asia. MSV International Development Paper No. 10. East Lansing Michigan: Michigan State University.

Dowswell, C.R., R.L. Palwal and **R.P. Cantrell** 1996. Improving Maize Technology Delivery Systems in the Third World. Westview Press Inc.; A Division of HarperCollins Publishers, Inc.

Edache, O.A. 1999 Agricultural Policy in relation to sustainable maize production in Nigeria. In; *Valencia, J.A. et. Al. eds. 1999. Sustainable maize Production in Nigeria. The challenge in coming millennium p. 24-32.*

Elemo, K.A. 1993. Maize Agronomy Research in the Nigerian Savanna. In; *Fakorede, M.A.B; Alofe, C.O. and Kim, S.K. (eds). Maize Improvement, Production and Utilization in Nigerian.*

FAO, 1997._*Quarterly Bulletin of Statistic Vol. 10 no 1/2*

Okoruwa, A.E. and J.G. Kling.1996. Nutrition and quality of maize. IITA Research Guide 33 pp 33.

Schoubroeck, F.H.J.; M. Herens; W. de Louw; J.M. Louwen and T.O. Overtoom, 1989. Managing pests and pesticides in small scale agriculture. Center for Development work, the Netherlands (CON).

Schulz, S. 2000. Farmer participation in research and development: the problem census and solving technique. IITA Research Guide 57 pp 22

World Bank, 1989. International Bank for Reconstruction and Development Report. In

Table 1: Technical efficiency of technology delivery systems in major maize environments of selected countries

Country	Environment	Economic yield potential (t/ha)	Estimated actual yield (t/ha)	Technical efficiency (%)
United States	Temperature	9.0	7.5	85
China	Temperature	6.0	4.8	80
Pakistan	Subtropical	3.5	1.4	40
Thailand	Tropical	3.5	2.5	71
Philippines	Tropical	3.5	1.5	40
Egypt	Subtropical (irrigated)	6.5	5.9	90
Benin	Tropical	3.5	1.0	29
Ghana	Tropical	3.5	1.4	40
Nigeria	Tropical	3.5	1.4	40
Kenya	Tropical (Highland)	3.5	1.4	40
Zimbabwe	Tropical-Mid-attitude	4.5	1.8	45
Argentina	Temperate	6.0	3.5	58
Brazil	Tropical	4.0	2.2	55
	Subtropical	3.0	1.4	47
Ecuador	Tropical	3.5	2.0	57
	Highland	4.0	1.5	38
Guatemala	Tropical	4.0	2.0	50
	Highland	4.0	1.5	38
Mexico	Subtropical	4.0	2.5	63
	Highland	4.0	1.6	40

Optimum yield potential, given current input prices, availability of technology, and farmer management skills, as determined from farmer-managed on-farm research trials.
Sources: FAO and Dowswell et. Al., (1996)

TOWARDS DISSEMINATION OF QUALITY PROTEIN MAIZE TECHNOLOGY IN NIGERIA

S.S. Abubakar [1], S.J. Auta[2], J.G. Akpoko[2], and J.E. Onyibe[2]*

INTRODUCTION

Maize is a major food and industrial crop in Nigeria. Its genetic plasticity has made it the most widely cultivated crop in the country from the wet evergreen climate of thr forest zone to the dry ecology of the Sudan savanna. National production is put at 6.14 million tones on an area of 3.78 million hectares (NAERLS 1999). Maize is used directly for human food, constituting about 60-70% of the dietary profile of adults and over 80% of that of infants. It is widely fed to weaning children with or without any protein supplement. About 30-40% of annual production is used as livestock feed.

Maize contains about 10% protein, but the protein has been found to efficient in two amino acids –lysine and tryptophan (NRC,1988). Human being and other monogastric animals do not synthesize these amino acids and may therefore need these protein supplements. In order to provide a balance dietary profile in maize based food and feeds; fortification with grain legume such as soybean and groundnut is prevalent. The widespread use of these grain legumes especially at industrial level has raised demand for legumes beyond what a majority of potential users can afford.

The development of quality protein maize (QPM), which contains higher level of lysine and tryptophan has great potential for partially compensating for a protein energy deficiency in the energing food habit. Also, the use of QPM in feeds has potential for improving the quality of feeds and reducing the level of fortification with legumes. The would indirectly reduce the cost of feed supplements in livestock husbandry, it would also indirectly improve human diets through improvement of the quality of livestock that has been maintained on QPM. In essence therefore, QPM has high prospect of impacting positively on the Nigerian populace.

However, the opportunities that are available following the development of QPM are not yet known to target beneficiaries (farmers, households and industrial users of maize). Hence, like every new biotechnology, the awareness of the use and cultivation of QPM has to be created and sustained. Extension services in Nigeria having successfully promoted the cultivation of maize which now extends far into marginal zones of Sudan savanna of Nigeria, still holds keys to a successful stimulation and sustenance of farmers' interest in this new variety of maize.

This paper discuss the strategies towards dissemination of QPM technology in Nigeria. The first part of the paper highlights the constraints to adoption of maize technology. This is followed by methodologies often used in

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the dissemination of technologies dissemination. The paper concludes with recommendation drawing experience with agricultural technology dissemination in Nigeria.

Constraints to Self-sufficiency in Maize Production

Demand for maize is increasing at a fast rate. Unfortunately, constraints to meet this ever-increasing demand manifest themselves in production volume that is lower than that achievable. These constraints have been summarised (Fajemisin, 1995) as follows:

i) Extensive use of local, low-yielding maize varieties
This is, to a large extent, due to inadequate supply of seed improved, high-yielding varieties.

(ii) Low soil fertility and non-widespread use of fertilizers. Soils in the forest zone rapidly lose fertility a few cropping seasons after clearing from the natural buffered forest cover. In the savannas, soils are low in organic matter, nitrogen phosphorus and secondary nutrients.

(iii) High cost and inappropriate methods of land clearing

(iv) Land tenure problems –difficulties in obtaining land in the desired ecology and / or inadequate size.

(v) Inadequate and often untimely supply of production inputs –fertilizer, herbicides, pesticides and machinery.

(vi) Low productivity due to losses from weeds diseases and insects.

(vii) Prevailing management practices are labour-intensive-slow, uninteresting, expensive and, therefore, not economical and socially rewarding.

(viii) Draught is a major case of production instability –this is more frequent and serious in the north. It may occur two to three weeks following the first rains, or flowering or the season's rainfall may cease well ahead of long-term average.

(ix) Lack of easily obtainable credit facilities.

(x) Lack of effective, organized produce marketing system.

(xi) Need for consistence government policy –one that encourages production rather than create disincentives as rational input-subsidies, assistance in land clearing and discouraging maize importation.

(xii) Varieties preference
Several factors (Figure 1) such as colour, yield, kernel type / characteristics, compatibility with traditional food habits, fertilizer requirement, plant height, tolerance to striga, seed purity and climatic/weather factors have also bee identified to influence farmers' choice of maize (Arokoyo et. Al., a996 and NAERLS. 1996).

Extension Methodologies in the Dissemination of Agricultural Technologies

The extension teaching methods that have been used over years in Nigeria fall into three basic categories: individual contacts, mass communication and the group approach.

a) **Individual contacts**

Individual contacts involved personal visit to the farmers to hold personal discussions and / or teach the farmers techniques. Individual visits allow two-way communication process between farmers and extension workers. It often leads the development of mutual confidence and trust, a pre-requisite to greater receptivity of new ideas. Unfortunately, the of extension workers is too small compared with the population of farmers to be served. The acute shortage of extension personnel, the large population of farmers and the widely scattered nature of farms, all limit the scope for the use of individual approach to agricultural education

b) **Mass Communication**

Mass communication as a means of extension education involves the use of printed materials, film shows, radio and television talks, etc. Fir teaching farmers and making them aware of new techniques. It finds its widest application in a situation where is high proportion of literacy and there is adequate provision of infrastructures such as good roads, electricity, television, radio etc. it can serve as an effective medium of teaching when the subject matter is not complex or where simple information is to be passed to farmers. It is effective in reaching a large number of farmers within a very short period of time.

One of its major advantages is its impersonal nature. There is no face-to-face contact and the development of mutual contact characteristic of individual contact is lacking. Mass media is not yet an effective and widely used method of agricultural education because of the illiteracy of the farming population and the poorly developed infrastructures

c) **Group approach**

The group approach to agricultural education is the most commonly used method of agricultural extension education. The group approach includes farm demonstrations (either method of results); farm talks or walks, agricultural shows, group meetings, etc. Since farm families traditionally live together in villages, it becomes possible to give talks, farm demonstration, farm walks, etc. to a large group of farmers.

Extension Strategies for QPM Technology Dissemination

The primary role of extension will be to create a desire to adopt the production and utilization of QPM. Generally, the role of extension will include amongst others to:

(i) Create awareness / interest of target groups on QPM;
(ii) Identify and confirm sources of good quality and suitable QPM seeds;
(iii) Organised farmers into community- based and strengthening the capacity of NGOs/ contract seed growers;
(iv) Train relevant extension agents and farmers on production and utilization QPM;
(v) Promote / introduce QPM through a variety of sustainable extension methodologies; and
(vi) Ensure production of good quality seed and identify source for QPM products marketing.

The above-cited roles could be through the use and provision of the following:

(a) **Use of the mass media:**

The use of the mass media such as radio, television, and extension publications should widened in order to reach many more farmers with different backgrounds, interest and inclinations. Radio is the best tool for creating awareness in such a new idea as QPM in all hooks and corners of Nigeria within the shortest possible time. Radio has the advantage of reaching the large majority of Nigerians irrespective of sex, language, cultural and physical barriers. The television on the other hand , is a powerful tool which can not only be used for creating awareness and interest, but also to teach and demonstrate to the target groups, the production and utilization techniques of QPM. Extension publication such as posters, guides, magazines newspapers, news letters, etc. written particularly in vernacular could help to sensitise the target groups on QPM. They are also effective means to conveying specific technical detail information on the production of QPM. If well organized and publicised, agricultural shows could serve as an important medium of agricultural education. Farm demonstrations appears to be the most effective and widely used method of creating farmer's awareness on new techniques or convincing farmers about agricultural innovations. Since predominantly illiterate farmers are generally inductive orientated, demonstration brings the points home clearly to the farmers and credence to the superiority of the practices being demonstrated. Organized walks and talks are usually arranged as part of agricultural demonstrations during which the farmers can ask questions and change ideas with extension agents. The organized walks, talks and exchange of ideas between the farmers and agricultural firms' officials could go a long way in creating awareness. Visual aids and demonstration which integral part of agricultural show often increase farmers' awareness and create lasting impressions on the farmers.

(b) **Production and Supply of Good Seeds**

Good seeds are often the basis of the acceptance and impact of any crop anywhere in the world. Other inputs such as fertilizers and agro-chemicals are only additives, which require good seeds as foundation, before their full impacts can be felt. It is also obvious that the private sector is better suited for the supply and distribution of good quality inputs. It is recommended, therefore, that the private sector should be given the responsibility of making QPM seeds available to farmers. The private sector's role should largely be restricted to providing the enabling environment, the regulatory framework and funding facilitating institutions (e.g. research institutions, regulatory agencies) that will make the private sector function efficiently in making good quality seeds available to farmers at the right time and places, and at affordable prices. The government efforts in providing the enabling environment should center around providing appropriate laws and regulations and their operations should, however, not serve as impediments to private sectors operators. Additionally, extension will have to empower the farmers with the knowledge of identifying suitable seeds. Several attributes of maize variety such as colour, yield, kernel type/ characteristics, compatibility with traditional food habits, fertilizers requirement, plant height, tolerance to striga, and climate/ weather factors have also been identified to influence farmers choice of maize varieties. Accordingly, the following recommendations are offered:

i) **Colour:** Studies show that considerable differences exist between communities in terms of colour preference in maize acceptance and adoption (Figure 1). While the feed industries prefer yellow maize to white maize because of the high carotene content of the former, most households in Northern Nigeria prefer the white for the making "tuwo". These factors warrants the need to provide varieties of QPM in both colours in order to facilitate early acceptance and adoption.

ii) **Yield:** It is important that the QPM has high yield potential in addition to its high protein content as lower yields is likely to impede its adoption.

iii) **Kernel type / Characteristics:** Kernel characteristics (especially in terms of texture and density) should allow for ease grinding, resistance to pest attack and other factors which can affect acceptance by farmers and consumers.

iv) **Compatibility with traditional food habit:** There is need to ensure that there is no adverse change (not even subtle change) in appearance, texture and flavour when QPM is used in the preparation of indigenous foods when compared with conventional maize varieties consumed.

v) **Fertilizer requirement:** Chemical fertilizers are still expensive and not available in sufficient amounts. It would therefore be desirable that nutrient demand by QPM varieties should not exceed those of the conventional maize variety being grown. This also stresses the need to develop nutrient efficient varieties of QPM.

vi) **Plant height:** Farmers have other uses for maize straw as a source of forage for livestock and for domestic use such as roof thatching, and fencing of compounds. For these reasons the height of the QPM should also pro vide for these other uses of maize.

vii) **Tolerance to Striga:** Striga is a major parasite of cereals especially maize in Nigeria. It may therefore be necessary that QPM varieties have some measure of tolerance to striga infestation.

viii) **Seed Purity:** There is need for a seed delivery system which will ensure multiplication and distribution of pure seeds of QPM. The possibility of having composite varieties which can be replanted while still retaining desirable qualities should be exploited. Seed purity is of particular concern especially because QPM is indistinguishable in appearance from the conventional maize varieties currently available.

ix) **Climate/Weather Factors:** In the drier part of Nigeria, where many places seldom receive an average rainfall higher than 25mm, some level of drought tolerance would be necessary in QPM. However, the varieties to be promoted should not be susceptible to lodging. Another option would be to incorporate QPM into the early and extra-early maize varieties that can be introduced into there drier areas. In order to ensure sustainable of QPM adoption, therefore, it is proper to incorporate farmers' preferences and climatic conditions at the developmental stages.

(c) **Setting up a Suitable Machinery for Quality Seed Production**

Nigeria is the lack of suitable mechanisms for seed production. The problem may be more serious with the QPM seed production. Suitable QPM seed production and distribution in could possibly be fostered through the strengthening of local community-based seed producing organizations. Farmers groups, NGOs and individual contract seed producers are increasingly becoming important in Nigeria. Initially, surveys should be conducted by the national extension services in order to identify the resource capabilities of local community organizations and farmers to be contract growers. These groups and individual contract farmers should be provided with the necessary inputs and foundation seed on credit to produce certified seeds. These seeds should be directly to the extension services which then deducts input costs.

(d) **Training of both Farmers and Extension Agents on QPM Production Techniques**

This is necessary because of the newness of this technologies. Special handling is generally required for any quality maize to avoid cross pollination. This is important because genetic contamination is a potential problem. Farmers need to be trained in the techniques of seed production and how to secure good seed of the QPM. Training on QPM processing is also of importance. Some training may be necessary to ensure that normal methods of processing do not contaminate the proteins. Also new form of food such as tortillas and tortilla chips can be introduced.

Training of field extension staff can be formal and informal. Informal training can be done in one to five days while formal training are certificate training that can last from a few days to several weeks.

Training of farmers and rural households should however be a continuous exercise. Such training should focus on a particular aspect / topic at a time and should not exceed one day.

(e) **The Use Participatory Approach in which Decisions are made as much Possible by the Farmers**

The participatory approach is one of the effective and sustainable approaches being promoted in recent years in a number of countries. The participatory approach is based on the fact that many agricultural problems can no longer be solved through individual decision-making. Participation of the target group in collective decision Is required. This is in sharp contrast with other approaches where the farmers are often treated as ignorant recipients of information, rather than knowledgeable partners in programme implementation. Farmers have information which is crucial for planning a successful agricultural programme, including their goals, situations, knowledge, experiences with technologies and the social structure of their society, and they will be more motivated to cooperate in agricultural programme if they share responsibility for it. In a democratic society, it is generally accepted that the people involved have the right to participate in decisions-making about the goals they hope to achieve. The participatory is recommended for the dissemination of the QPM technology.

In order to facilitate technology dissemination using the participatory approaches, areas that need to be carefully explored include:

i) The encouragement of interaction between non-governmental agencies, and farmers;
ii) Promotion of the participation of farmers, and farmers group organizations. Several farmers groups exist through which information on QPM can be targeted. Farmers groups are a particularly good means of extension communication as people are more inclined to respond to the pressures and opinions of groups in which they are involved;
iii) Fostering of the participation of farmers, and farmers' organizations in problem diagnosis, technology testing, selection and dissemination;
iv) It had been suggested in several literature that networking, information collection and exchange among countries can help accelerate progress in both research and technology transfer. New knowledge or innovations therefore need to be inventoried, checked, stored, and made widely available through networking and exchange of information on QPM, and.
v) Targeting other categories of farmers other than small-scale rural farm households should be accorded some priority. This because increasingly, youths, women, urban farmers, medium and large scale farmers are being recognized as important contributors in aggregate agricultural production in Nigeria. Extension strategies which specially address the problems of these categories of farmers should be utilized in reaching them. Specialized such as the Management Training Plot (MTP) approach by SG2000 and Community Based Extension approach, are other methods that can be adopted to promote QPM. They are both tools got technology dissemination.

(f) **Organization of Effective Marking System**

The lack of effective marketing system in Nigeria has created problem in maize production. Although farmers are sometimes aware that prices are lowest soon after harvest, most farmers sell up their harvest within the first three months after harvest to meet immediate cash needs. Subsequently, maize supply to the market are controlled by traders and not producers. Consequently, the benefit of maize of maize production accrues to the traders rather than the producers. Low prices are also often obtained by farmers who produce poor quality maize grains. A steady price for maize grains that is beneficial to the producers should be evolved. Extension should insure that farmers produce poor quality maize grains that will attract good market prices. There will also be the need to educate the farmers on the importance of farmers storing their produce during peak periods. This will enable them obtain good prices by selling at the appropriate time thereby enhancing their income and it will serve as a source of encouraging high levels of adoption. The Government should also make regulations on the use of standard measures that are beneficial to the producers, nation-wide. The linkage between research and the private sector producer and marketers of maize products must be strengthened.

(g). **The Need for Consistent Government Policies**

Inconsistency of government policies has been identified as a constraint. Today it is subsidy removal, tomorrow is another different policy. Under such uncertainty investors of production inputs are discouraged. Similarly, price instability due to the inconsistency of government policy on ban and importation of competitive food items as well as across the border trade, are other constraints. A case in point is the consistency in the policy of the ban and importation of barley and wheat-two grains that are good substitutes for maize as materials for the bread and brewery industries. Maize is also unofficially, but actively traded across Nigeria's borders in a bid to earn foreign exchange. Indeed, the inconsistencies in national policy on trade control have had unbeneficial effect on maize farmers. It is recommended that to sustain the production of QPM, government should be consistent in its trading policies, which are beneficial to then farmers; that is policies that encourage production rather than create disincentives.

h). **Adequate Funding and Proper Organization of Research and Extension**

Finally, both research and extension on QPM should be adequately funded and properly organized. Research must new and appropriate seed varieties, while extension must make them available to the farmers. The private sectors must provide with fund to supplement government expenditure on research, while research must generate new and appropriate seeds for the private sector to produce and sell.

Conclusion Quality protein maize has a lot of potential for increasing the protein requirement of the Nigerian populace. This paper identifies factors that could influence adoption of QPM. A multi-dimensional broad-based approach requiring broad based participation and a mix of extension methods of advocated for the promotion of QPM.

The critical question that research and extension will, however, have to answer sooner or later will be "How far should QPM go in the replacement of the conventional maize varieties being grown in Nigeria?"

REFERENCES:

Abubakar S.S. Akpoko, J.G. and **Onyibe J.E.,** 1999. The role of Agricultural Extension in Sustainable Maize Production in Nigeria. In Valencia et. Al. (ed). Sustainable Maize Production in Nigeria: The challenges in the coming Millennium, Proceedings of the National Maize Production Workshop SG2000 / IAR / FMRD / ADPs 22nd—24th July, 1999 p.33-42

Arokoyo, J.O. Onyibe, J.E., daudu C.K., Akpoko J.G. Inwafor E.N.O. and **K.A.Elemo,** 1996, Promotion of Maize Technology Transfer in the Savanna Ecology of Nogeria: 1996 Annual WECAMAN Project report 20pp

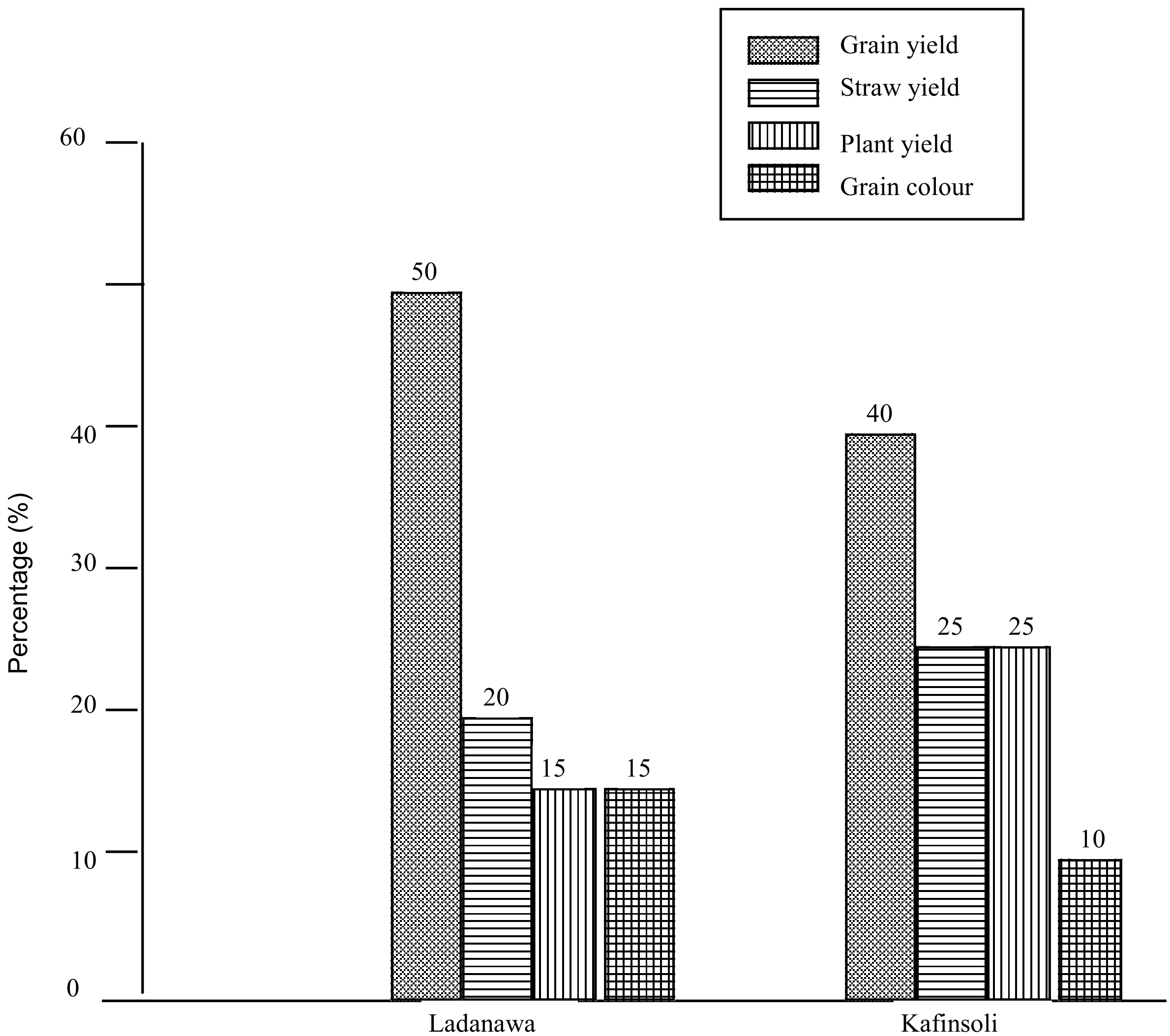
Fajemisin, J.M.., 1995. Status of Maize Production Technology in Nigeria and Prospects for Sustained Self-sufficiency. Paper Presented at the NAFPP 3rd joint Workshop held at Owerri, Imo State, Nigeria, March 7-0, 1995.

Idachaba, F.S.,1988. Extension Service and Institutional Linkages in Universities of Agriculture. In: M. Shittu and M.T. Garba (Eds): Proceedings of National Seminal on Universities of Agriculture, Nigrian University Commission, Lagos.

NAERLS, 1999. Maize Production in Nigeria. Extension Bulletin No. 11.

National Research Council, 1988, Quality Protein Maize, National Academy Press, Washington, D.C.

Valencia, J.A. and Breth: S.A. 1999. Maize Technology Transfer. The Sasakawa Global 2000 Experience in Nigeria. In Valencia et. Al. (ed). Sustainable Maize Production in Nigeria; the Challenges in the coming Millennium Proceedings of the National Maize Production Workshop. SG2000 / IAR / FMRD / ADPs 22nd -24th July, 1999 p.33-42.



EXPECTED ROLE OF EXTENSION IN THE PROMOTION OF QUALITY PROTEIN MAIZE

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INTRODUCTION

maize is a major food and industrial crop in Nigeria. Its genetic plasticity has made it the most widely cultivated crop in the country from the wet evergreen climate of the forest zone to the dry ecology of the Sudan savanna. National production is put at 6.14 million tones on an area of 3.78 million hectares (NAERLS 1999). Maize is used directly for human food, constituting about 60-70% of the dietary profile of adults and over 80% of that of infants. It is widely fed to weaning children with or without any protein supplement. About 30-40% of annual production is used as livestock feed.

Maize contains about 10% protein, but the protein has been found to be deficient in two amino acids –lysine and tryptophan (NRC,1988). Human being and other monogastric animals do not synthesize these amino acids and may therefore need these protein supplements. In order to provide a balance dietary profile in maize based food and feeds; fortification with grain legume such as soybean and groundnut is prevalent. The widespread use of these grain legumes especially at industrial level has raised demand for legumes beyond what a majority of potential users can afford. The high dependence on maize for food and the increasing cost of legumes has resulted in increasing cases of potential protein deficiency, especially among children. The development of quality protein maize (QPM), which contains higher level of lysine and tryptophan has great potential for partially compensating for a protein energy deficiency in the emerging food habit. Also, the use of QPM in feeds has potential for improving the quality of feeds and reducing the level of fortification with legumes. This would indirectly reduce the cost of feed supplements in livestock husbandry. It would also indirectly improve human diets through improvement of the quality of livestock that have been maintained on QPM. In essence therefore, QPM has high prospect of impacting positively on the Nigerian populace.

However, the opportunities that are available following the development of QPM are not yet known to target beneficiaries (farmers, households and industrial users of maize). Hence, like every new biotechnology, the awareness of the use and cultivation of QPM has to be created and sustained. Extension services in Nigeria having successfully promoted the cultivation of maize which now extends far into marginal zones of Sudan savanna of Nigeria, still holds key to a successful stimulation and sustenance of farmers' interest in this new variety of maize.

This paper discusses the role of extension in the introduction, acceptance and adoption of QPM. The paper also highlights key issues for consideration in order to ensure a sustain-

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able adoption of QPM, drawing experience from framer preferences and food culture of the Nigerians.

Previous Extension Efforts to Promote Maize Production and Utilization

The first major effort to promote massive production of maize in Nigeria was in 1971 through the Federal Government supported National Accelerated Food Production Programme (NAFPP) on pilot basis (Idachaba, 1988). The role of extension under this programme was to pass information on improved maize production practices to farmers and obtain feedback on farmers problem back to research. Extension also has a role of helping farmers gain access to necessary farm inputs. There was also another government supported programme in 1976 tagged "Operation Feed the Nation". This programme however had virtually no articulated role for extension. The Agricultural Development Project (ADPs) system, which is an integrated rural development approach was first initiated at pilot level in Funtua, Gusau and Gombe in 1975. The key features were mechanisms for problem identification and prioritisation, active linkage with farmers which allowed for feedback and training. The ADPs have an agricultural extension component using the training and visiting system, and had extended nation wide now. The ADPs work closely with research institutes. A considerable number of recommended maize varieties and recipes have been promoted through these projects (Abubakar *et. al*. 1999).

Through the use of Management Training Plot Approach (MTP) popularised by Sasakawa Global 2000 farmers maize yield have been doubled in the Northern Guinea savanna (Valencia and Breth, 1999). The West and Central African Maize Network (in an NAERLS / IAR collaborative project) used a participatory model in a community based extension approach to stimulate the production of early and extra-early maturing varieties of maize in the savannas. Both approaches have achieved significant level of success while working in collaboration with ADPs. These approaches may need to be adopted to promote the QPM.

Factors Affecting Adoption of Varieties:

Research on the potential of QPM in Nigeria is very recent and critical recommendations are currently being finalised. Several factors have been identified to influence farmers choice and variety preference (Arokoyo *et. al.* 1996 and NAERLS. 1996). In order to ensure sustainable recommendation, it is proper to incorporate farmer preferences at the developmental stages. According to Arokoyo *et al.* (1996) and NAERLS. (1996) the following attributes will be relevant to the promotion of QPM:

a. **Colour**: Arokoyo *et. al*. (1996) reported that considerable differences exist between communities in terms of colour preference in maize acceptance and adoption, while farmer choice and preference in selection of maize varieties are dependent mainly on grain yield and some other factors (fig.1). The figure also shows the diversity in factors that influence adoption of any particular variety of maize. While the feed industries prefer the yellow maize to white maize because of the high carotene content of the former, most households in Northern Nigeria prefer white "tuwo" made from white maize. These factors warrant the need to provide varieties of QPM in both colours in order to facilitate early acceptance and adoption.

b. **Yield**: maize farmers are beginning to get used to high yields of maize under the MTP and community based extension approach. It is important that QPM has high yield potential in addition to its high protein content as lower yield is likely to impede its adoption.

c. **Kernel type / characteristics: Kernel** characteristics (especially in terms of texture and density) should allow for easy grinding, resistance to pest attack and other factors, which can affect acceptance by farmers and consumers.

d. **Compatibility with traditional food habit:** There is need to ensure that there is no adverse change (not even a subtle change) in appearance, texture and flavour when QPM is used in the preparation of indigenous foods when compared with conventional maize varieties consumed.

e. **Fertilizer requirement:** Chemical fertilizers are still expensive and not available in sufficient amounts. It would therefore be desirable that nutrient demand by QPM varieties should not exceed those of the conventional maize varieties being grown. This also stresses the need to develop nutrient efficient varieties of QPM.

f. **Plant heigh**t: Farmers have other uses for maize straw as a source of forage for their livestock and domestic use such as thatching of roof, and fencing of their compounds. For this reason the height of the QPM should also provide for this other uses of maize. However, varieties to be promoted should not be susceptible to lodging.

g. **Tolerance of striga:** Striga is a major parasite of cereals, especially maize in Nigeria. It may therefore, be necessary that QPM varieties have some measure of tolerance to striga infestation.

h. **Seed purity:** There need for a delivery system which will ensure multiplication and distribution of pure seed of QPM. The possibility of having composite varieties which can be replanted while still retaining desirable qualities should be exploited. Seed purity is of particular concern especially because QPM is indistinguishable in appearance from the conventional maize currently available.

i. **Climatic / weather Factors:** In the drier part of Nigeria, where many places seldom receive an average rainfall, some level of drought tolerance would be necessary in QPM. Another option would be to incorporate QPM into early and extra-early maize varieties that can be introduced into these drier areas. Extension must therefore ensure that farmers are fully involved at all stage of planning, identification and appraisal of QPM varieties. This is important also because when selection of suitable varieties is done in collaboration with farmers, it increases early acceptance of QPM.

Expected Role of Extension in the Promotion of QPM

The primary role of extension will be to create a desire for change (to the production and utilization of QPM) and, to influence farmers and consumers to take action that bring this change. Generally, the role of extension will include amongst other:

i. Identify and confirm suitable QPM varieties through multilocational trials.

ii. Create awareness / interest of target group in QPM

iii. Train relevant extension agents and farmers on production and utilization of QPM

iv. Promote / introduce QPM through a variety extension methodologies

Coordination of Promotional Efforts:

There is need for identification of relevant stakeholders in promotion exercise and for extension to coordinate their efforts. The potential stakeholders in promotional efforts related to QPM will include research institutes (both local and international), extension and extension support agencies, NGOs, health / nutrition agencies; farmers and consumers of QPM. Consumers of particular interest include children of all age (with emphasis on weaning babies), nursing mothers, livestock farmers, food industries etc. High prospect exists for the involvement of all of these stakeholders in the promotion of QPM which will warrant coordination of the effort in order to avoid duplications, reach consensus on critical issues and formulate effective strategies for the promotion and adoption of QPM. There is no doubt that multi-sectoral involvement in promotional efforts will evoke the use of different extension methods. Some of the potential extension methods that may be adopted are presented bellow:

Extension Methods:

Extension methods comprise of channels (techniques of communication) through which farmers and other target groups are motivated and enhanced to address their problems. It would be advisable to use a wide variety of extension methods as possible to ensure rapid dissemination of QPM. Extension methods are classified into two main groups viz:

1.**Mass Methods:**

This method aims at reaching most of the target groups at the same time. It involves the use of all available media such as:

Electrical media: the electrical media will include radio and television broadcasts, internet etc.

(i) **Radio**: This is probably the effective communication tool used in Nigeria today to communicate to farmers and the general public. It overcomes the problems of distance, time, poor roads and illiteracy. Radio is the best tool for creating awareness and interest in such new ideas as QPM in all nooks and corners of Nigeria within the shortest possible time. Radio has the singular advantage of reaching the large majority of Nigerians irrespective of sex, language, cultural and physical barriers.

(ii) Television (and internet)

Compared to radio, these two are confined to areas where electricity is available and stable. While internet is further restricted by access to telephone and computers. Thus the internet despite its potential is not likely to be of much use in QPM promotion for now.

The radio and television and print media are powerful tools which cannot only be used for creating awareness and interest, but also can be used to teach and demonstrate to the target group the production and utilization techniques for QPM.

Print media: The print media that could be adopted to extend QPM technology include; Newspapers, Magazines agricultural extension publication etc.

2. **Newspaper / Magazines:**

The use of timely release in Newspaper, Magazines, Newsletters etc. (particularly in vernacular versions)) will help sensitize the target group on QPM.

Extension Publication:

Posters, Flipbooks and Guides are channels of disseminating information on QPM. They are particularly effective for conveying technical details for production on QPM. However, the more it is used to supplement the mass extension, the greater the amount of success achieved.

3. Group Methods:

This is an approach in which several members of the target group who are linked with formal and informal ties are addressed at the same time. It is the most important method as it permits more participation by the target groups, and saves extension costs and time. Group methods include:

(a) Demonstration: The result demonstration will have to establish proof that utilization of QPM is more beneficial and more economical than any other maize varieties. This could be through comparison of livestock fed on QPM and other maize varieties. This result can also be used for open days, agricultural shows and fairs etc. Demonstration can be used to show farmers QPM production techniques.

(b) Farmers' Groups: Several farmers' groups exist through which information on QPM can be targeted. Farmers' groups are a particular group means of extension communication as people are more inclined to respond to the pressures and opinions of groups in which they are involved.

(c) Specialised approaches: Such as the MTP approach by SG2000 and Community Based Extension Approach Developed by NAERLS referred earlier are other methods that can be adopted to promote QPM. They are both tools for technology demonstration.

(d) Agricultural show / Field days / Fairs: these are activities organized to allow farmers learn technologies and ask relevant questions.

Mass methods when used in combination with individual and group methods could be a very productive means of dissemination of QPM

Extension Training

There is a strong need for training both the farmers and extension agents on QPM production techniques because of newness of this technologies. Special handling is generally required for any quality maize to avoid cross pollination. This is important because genetic contamination is a potential problem. Farmers need to be trained on how to secure seeds of the QPM. Training on how QPM processing and utilization is also of some importance. Some training may be necessary to ensure that normal methods of processing do not denature the proteins. Also new forms of food can be introduced.

Training field extension staff can be formal and informal, informal trainings can be done in one to five days while formal trainings are certificated trainings that can last for a few days to several weeks.

Training of farmers and rural households should however be continuous exercise. Such training should focus on particular aspect / topic at a time and should not exceed one day.

CONCLUSION

Quality protein maize has a lot of potential for impacting positively on the food habit of the Nigerian populace. The role of extension is to stimulate and sustain the production and utilization of QPM with collaborative efforts with Farmers, Research and potential users of QPM. This paper presented the menu of extension options that could be adopted for the promotion of QPM and suggested the need to involve farmers in the screening promising varieties and recipes. The paper identifies factors that could influence adoption of QPM. A multi -dimensional broad-based approach requiring broad-based participation and a mix of extension methods Is advocated for the promotion of QPM.

The critical question that research and extension will have to answer sooner or later will be “How far should QPM go in the replacement of conventional maize varieties being grown in Nigeria”

REFERENCES:

Abubakar S.S. Akpoko, J.G. and **Onyibe J.E.,** 1999. The role of Agricultural Extension in Sustainable Maize Production in Nigeria. In Valencia *et. al.* (ed). Sustainable Maize Production in Nigeria: the challenges in the coming Millennium, Proceedings of the National Maize Production Workshop SG2000 / IAR / FMRD / ADPs 22nd—24th July, 1999 p.33-42

Arokoyo, J.O. Onyibe, J.E., daudu C.K., Akpoko J.G. Inwafor E.N.O. and **K.A.Elemo,** 1996, Promotion of Maize Technology Transfer in the Savanna Ecology of Nogeria: 1996 Annual WECAMAN Project report 20pp

Idachaba, F.S., Extension Service and Institutional Linkages in Universities of Agriculture. In: M. Shittu and M.T. Garba (Eds): Proceedings of National Seminal on Universities of Agriculture, Nigrian University Commission, Lagos.

NAERLS, 1999. Maize Production in Nigeria. Extension Bulletin No. 11.

National Research Council, 1988, Quality Protein Maize, National Academy Press, Washington, D.C.

Valencia, J.A. and Breth: S.A. 1999. Maize Technology Transfer. The Sasakawa Global 2000 Experience in Nigeria. In Valencia et. Al. (ed). Sustainable Maize Production in Nigeria; the Challenges in the coming Millennium Proceedings of the National Maize Production Workshop. SG2000 / IAR / FMRD / ADPs 22nd -24th July, 1999 p.13-23.

APPROACHES TO IMPROVING THE NUTRITIVE VALUE OF MAIZE WITH PARTICULAR EMPHASIS ON QPM

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ABSTRACT

Maize is a basic staple food for large population groups around the world particularly in developing countries. Its low nutritional value particularly with respect to its protein quality has been of concern to Agriculturalist, Nutritionist and Policy Makers. Accordingly, substantial progress has been recorded in improving its protein quality culminating in the development of a good quality variety, popularly known as Quality Protein Maize (QPM).

A lot effort has been made to improve the biological utilization of the nutrients contained in different maize varieties. Three approaches have been tried; namely, genetic manipulation, processing and fortification. This paper discusses briefly progress so far recorded in these processes.

1.0 INTRODUCTION

Maize (*Zea mays*), botanically a member of the grass family (*Gramineae*) is the third (after wheat and rice) most important cereal grain in the world (FAO, 1992). Of the three crops, maize has the highest yield per hectare. This advantage probably explains its wide utilization as food, feed for livestock and as raw material for industry. Maize is an important source of Carbohydrates, Proteins, Vitamin B and Minerals particularly in Africa where it is mostly used for human consumption. This papers discusses the nutritional quality of maize and survey the efforts made to improve the nutritive value of maize with particular emphasis on QPM in view of its importance to the nutritional well being of millions around the world.

1.1 NUTRITIONAL VALUE OF MAIZE : AN OVER VIEW

The importance of cereal grains to the nutrition of millions of people around the world is widely recognized. Because they make up such a large part of diets in developing countries, cereals cannot be considered only as a source of energy, as they provide significant amounts of protein as well. It is also recognized that cereal grains have a low protein concentration and that protein quality is limited by deficiencies in some essential amino acids, mainly lysine and tryptophan. Much less appreciated however, is the fact that some cereal grains contain an excess of certain essential amino acids that influence the efficiency of protein utilization. The classic example is maize. Other cereal grains have the same constraints but less obviously.

A comparison of the nutritional value of maize protein with the protein of some common cereals is given in Table 1.1 expressed as percentages of casein. The protein quality of common maize is similar to that of the other cereals except rice. Both opaque – 2 maize and Quality Protein Maize (QPM) have a protein quality not only higher than that of common maize, but also significantly higher than that of other cereal grains.

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Table 1.1 Protein quality of maize and other cereal grains

S/No.	CEREAL	**PROTEIN QUALITY** (% CASEIN)
1.	Common maize	32.1
2.	Opaque –2 maize	96.8
3.	QPM	82.1
4.	Rice	79.3
5.	Wheat	38.7
6.	Sorghum	32.5
7.	Barley	58.0
8.	Pearl Millet	46.4
9.	Finger Millet	35.7
10.	Oat	59.0

The reasons for the low quality of maize proteins have been extensively studied by numerous investigators. Among the first were Mitchell and Smuts (1932) who obtained a definite improvement in human growth when 8 percent maize protein diets were supplemented with 0.25 percent lysine. These results have been confirmed over the years by several authors. While others (et. al. 1968) have shown that the addition of lysine to maize causes only a small improvement in protein quality. These differing results may be explained by variations in the lysine content of maize varieties. Work in this field led to the discovery by Mertz, Bates and Nelson (1964) of the high-lysine maize called Opaque – 2.

In any case, it has been amply documented that, the addition of 0.30 percent L-lysine and 0.10 percent L-tryptophan easily increases the protein quality of maize by 150 percent.

The essential amino acid content of the major components of maize kernel is given in Table 1.2

Table 1.2 Essential amino acid content of germ protein and endosperm protein.

		ENDOSPERM		GERM	
S/No.	AMINO ACID	mg %	mg/gN	mg%	mg/gN
1.	Lysine	228	180	791	341
2.	Tryptophan	48	38	144	62
3.	Leucine	1,024	810	1,030	444
4.	Threonine	315	249	622	268
5.	Isoleucine	365	289	578	249
6.	Phenylalanine	359	284	483	208
7.	Tyrosine	483	382	343	148
8.	Valine	403	319	789	340
9.	Total Sulphur Amino Acids	249	197	362	156

1.2 **NUTRITIONAL VALUE OF QPM**

The protein quality of alkali-processed QPM was evaluated in children using the nitrogen balance index (the relationship between nitrogen absorption and retention). No significant differences in nitrogen retention was observed among the children fed the diets based on milk and on alkali – processed QPM when the level of protein intake was 1.8g per Kg per day (Bressani, et. al, 1969). The data demonstrated differences in nitrogen absorption. Nitrogen absorption from QPM and common maize was 70 and 69 percent respectively, and 82 percent from casein. Nitrogen retention as a percentage of intake was 32 percent for QPM as compared with 41 percent for casein and 22 percent for common maize. These results, like others reported by many workers, confirm the great superiority of QPM to common maize as food for children. Similar works on human adults also demonstrated the superiority of QPM over many other cereals as a source of good quality protein and overall nutritive value.

2.0 **METHODS OF IMPROVING THE NUTRITIVE VALUE OF MAIZE**

Given the importance of maize as a staple food for large population groups particularly in developing countries, and its low nutritional value, mainly with respect to protein, many efforts have been made to improve the biological utilization of the nutrients it contains. Three approaches have been tried:-

1. Genetic manipulation
2. Processing
3. Fortification

2.1 **GENETIC MANIPULATION**

2.1.1. **Carbohydrates**

The quantity and quality of the carbohydrate component of the maize kernel can be modified by breeding. The subject is being extensively reviewed by Boyer and Shannon (1983) and Shannon and Garwood (1984). Specific examples include:-

1. The waxy gene (*Wx*) in waxy maize has been shown to control amylopectin starch in the endosperm up to 100 percent with very low amounts of amylose.
2. The amylose extender gene (*Ae*) increases the amylose fraction of the starch from 27 to 50 percent.
3. Other genes cause an increase in reducing sugars and sucrose. Sugary (*Su*) genes produce relatively high amounts of water-soluble poly saccharides and amylose. Maize kernels containing this gene are sweet and are important in canning. Their starch content and quality also have nutritional implications, since some starch granules have low digestibility while others have high digestibility.

Some researchers (Sandstead, et. al, 1968) have suggested that maize varieties with waxy or sugary genes could be of better nutritional value for monogastric animals because of the greater digestibility of the type of starch they produce.

2.1.2. **Protein Quantity**

As early as 1948, Woodworth and Jugenheimer, demonstrated that total protein content could be increased by selection in an open pollinated variety or by crossing standard inbred lines with an HP strain followed by backcrossing and selection in segregating populations. Later, Tsai *et.al* (1983) concluded that full expression of the protein genes in maize can be attained with appropriate levels of nitrogen fertilizers; and that nitrogen fertilization of maize increased total protein because of an increase in prolamine content. Studies conducted by others, showed, however that the protein quality of the HP strains was lower than that of common maize since the increase in protein was due to an increase in the prolamine fraction. This led to the greater attention to improving protein quality rather than protein quantity.

2.1.3 Protein Quality

The low protein quality of maize stems mainly from the deficiency of the essential amino acids lysine and tryptophan. The feasibility of improving the quality of maize varieties were obtained from the early studies of Frey and Co (1949) that showed the genetic variability in tryptophan content in a cross between the Illinois HP and LP strains as well as in hybrids. However, as stated earlier, it was Mertz, et. al (1964) that reported the role of opaque –2 gene in significantly increasing the lysine and tryptophan content in maize endosperm. This gene also reduced the leucine level, giving a better leucine to isoleucine ratio. The same workers also showed that the floury –2 gene when homozygous could also increase the lysine and tryptophan levels in maize. Eventually, research conducted at CIMMYT yielded maize lines of QPM which agronomically behave like common maize.

The protein quality of QPM is significantly higher than that of common maize as shown by tests in humans. Although such types of maize are available, it has been difficult to grow them commercially even though the benefits to be derived from them by large maize consuming populations would be high.

2.1.4 Fat Content and Quality It has been shown through genetic studies that oil content in maize is subject to genetic influence, with diversity often found, although environment and agronomic practices can influence fatty acid composition. As with protein content, mass selection over 65 years increased oil content from 4.7 to 16.5 percent (Leibovits and Ruckenstein, 1983). The increase was obtained through increases in the size of the germ. Besides total oil content, some studies have shown that the fatty acid content may also be subject to genetic control, as seen by changes in linoleic acid content in maize oil. Poneleit and Alexander (1965) suggested a single gene or single-gene-plus modifier effect. A multi-gene system of inheritance has been proposed by other investigators. QPM oil fatty acid composition was found to be similar to that reported for normal maize.

2.1.5 Other Nutrients

In view of the association of maize consumption and pellagra and the low availability of nicotinic acid in maize, efforts have been made to increase niacin in maize by genetic processes. Results from 22 varieties planted in one location showed a variation in niacin content of between 1.25 to 2.6 mg per 100g. However, the problem of niacin in maize is its non availability to the animal organism. The other nutrient that have received attention is carotene. Researchers have shown that Vitamin A activity in yellow maize vary from 1.52 to 2.58 mg per gram. They have also indicated that provitamin A activity is under genetic control in the maize kernel.

2.2 PROCESSING

Processing of foodstuffs often stabilizes nutrients in the food but losses may also take place. However, the beneficial effects often outweighs the losses. Beneficial effects include the removal of anti physiological factors in foods and the improvement in the availability of essential nutrients. Such processes include:-

2.2.1 Alkaline Treatment of Maize

The alkaline treatment of maize widely practiced in Latin America has been shown to improve the availability of niacin, calcium and the essential amino acids especially lysine and tryptophan. Data from biological studies have shown significant improvement in the nutritive quality of maize diets and their support for optimal growth in both children and adults.

2.2.2 Fermentation and Germination

Natural fermentation of cooked maize has been shown to result in higher-B-vitamin concentration and protein quality. Germination of the grain has also been reported to improve the nutritional value of maize by increasing lysine and to some extent tryptophan and decreasing zein content. A similar result was found with QPM.

2.3. FORTIFICATION

Fortification is universally accepted as the most versatile approach of improving the nutritive value of foods especially cereal grains. Because of the great nutritional limitations in maize, many efforts have been made to improve its quality and particularly that of its protein through addition of amino acids or protein sources rich in the limiting amino acids.

2.3.1 Fortification with Amino Acids and Protein Sources

Many studies conducted with animals have demonstrated that the addition of both lysine and tryptophan have improved the quality of maize protein. Some workers have even found that besides lysine and tryptophan, isoleucine is also limiting in maize proteins. Many protein sources have been used to supplement and thereby improve the protein quality of maize flour. Such sources include casein, fish protein concentrate, soy protein isolate, soyabean flour, yeast, egg protein, meat flour, and cotton seed flour etc. Many studies have shown that maximum PER (Protein Efficiency Ratio) is achieved with the addition of other sources of protein such as the ones enumerated above.

2.3.2 Fortification with Green Vegetables and Other Sources

Some communities have the traditional habits of wrapping maize doughs in leaves. The young leaves of mature vegetables such as crotalaria and amaranthus have been used. Chemical and nutritional studies have demonstrated that about 95 percent contribution of these leaves improves the protein quality of the dough. The reason is that they have relatively high levels of protein rich in lysine and tryptophan. They also provide minerals and vitamins particularly provitamin A. Leaf protein concentrates have also been shown to improve the protein quality of cereal grains.

Many cereal grain flour mixtures have been tested and found to improve the nutritional quality of the end product. Such flour mixtures include sorghum/maize composite, wheat and maize, rice and maize and lately amaranth flour with maize flour. The amaranth lime cooked maize flour mixture has been shown to improve protein quality because of the higher lysine and tryptophan content of amaranth as compared with maize. The product has been reported to be of an acceptable organoleptic quality.

Complementation of both common maize and QPM maize with common black beans resulted in a 50% increase in PER. The nitrogen increase resulting into higher PER was constantly provided by QPM. A similar response was observed with mixtures of normal and QPM maize and soybean flour. The mixture is equivalent to 77 percent maize and 23 percent soybean flour on a weight basis. Many other mixtures of maize and other foods have been developed with common maize or QPM and other protein sources, giving products of high nutritional value and acceptability.

3.0 **CONCLUSION**

The evidences presented from chemical, biological and nutritional studies in both children and adults clearly indicate the superiority of QPM maize over common maize. In spite of this, only few countries such as Columbia, Guatemala and Ghana have made efforts during the last few years to introduce this superior maize into agricultural production systems. The reasons are not clear, since agronomic studies conducted in a number of locations have shown that there are no differences between QPM and common maize in cultural practices, yield per unit of land and physical quality of the grain. Furthermore, the plants look alike, QPM kernels are crystalline and grain yields are comparable to those of common maize. These factors are perhaps more important to growers than the nutritional advantages offered by QPM. Although energy content is alike in both types of maize, but the protein content of QPM is higher and is better utilized because of its better essential amino acid balance.

The nutritional advantages offered by QPM should be fully utilized in a country such as ours (Nigeria) where poverty level and malnutrition among children are relatively high. SASAKAWA GLOBAL 2000 as ever should lead this crusade.

REFERENCES CITED

Benton, D.A., Harper, A.E., Spivey, A.E. and Elherjem, C.A. ***1956.*** **Leucine, Isoleucine** and **Valine relationship**s ***in the rats. Arch. Biochem. Biophys., 60: 147-155***

BreZssani, R., Elias, L.G. and **Braham, J.E.** 1968. Supplementation con aminoacids del maiz y de la tortilla. *Arch. Latinoam. Nutr., 18:* 123:124

Bressani, R., Alvarado, J. and **Viteri, F.** 1969. Fevalucion en ninos de la Calidad de la proteinadel maiz o-paco-2 *Arch. Latinoam. Nutr., 19:* 129-140

Boyer, C.D. and **Shannon, J.C.** 1983. The use of endosperm genes for sweet corn improvement. In. J. Janick, ed. *Plant breeding reviews, Vol. I.,* P. 139-161. Westport, Conn., USA, AVI Publishing Co.

FAO, 1992 Maize in Human Nutrition. FAO Rome Italy 1992.

Frey, K.J. 1951. The interrelationships of proteins and amino acids in corn. *Cereal Chem.,* 28:123-132

Hogan, A.G., Gillespie, G.T., Kocturk, O., O'Dell, B.L. and **Flynn, L.M**. 1955. The Percentage of Protein in Corn and its nutrition properties. *J. Nutr. 57:* 225-239

Leibovits Z. and **Ruckenstein, C.** 1983. Our experiences in Processing Maize (Corn) germ oil. *J. Am. Chem. Soc., 60:* 395-399

Mertz, E.T., Bates, L.S. and **Nelson, O.E.** 1964. Mutant gene that changes protein composition and increases lysine content of maize endosperm. *Science 145:* 279-280

Michell, A.H. and **Smuts, D.B.** 1932. The amino acid deficiencies of beef, wheat corn, oats and soyabeans for growth in the white rate. *J. Biol. Chem., 95:* 263-281

Poneleit, C.G. and **Alexander, D.E.** 1965. Inheritance of Linoleic and Oleic acids in maize. *Science, 147:* 1585-1586

Sandstead, R.M., Hites, B.H. and **Shroeder, H.** 1968. Genetic Variations in Maize: Effects on the properties of the starches. *Cereal Science Today, 13:* 82-94, 156.

Shannon, J.C. and **Garwood, D.L.** 1984. Genetics and Physiology of starch development. In R.L. Whistler, J.N. Bemiller and E.F. Paschall, eds. *Starch Chemistry and Technology,* P. 25-86. Orlando, Fla., Academic Press.

Tsai, C.Y., Warren, H.L., Huber, D.M. and **Bressani, R.A**. 1983. Interaction between the Kernel N Sink grain yield and protein nutritional quality of maize. *J. Sci. Food Agric. 34:* 255-263

Woodworth, C.M. and **Jugenheimer, R.W.** 1948. Breeding and genetics of high protein corn. *Ind. Res. Rep., 3:* 75-83

POST-HARVEST TECHNOLOGY OF QUALITY PROTEIN MAIZE: STORAGE AND PROCESSING –CHOOSING THE RIGHT TECHNOLOGY.

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ABSTRACT

The efforts being made to improve productivity of maize in Africa include the introduction of high yielding varieties of quality protein maize (QPM). In order to maximise the benefits of improved production, attention must also be paid to improving post-harvest storage and processing to reduce losses and to maintain quality. The increases in yield that are possible can place a severe strain on the traditional post-harvest system; farmers have to cope with larger volumes of grain which is often more susceptible to attack by storage pests than traditional varieties. Storage losses can be minimised by introducing improved storage methods, including the use of pesticides or alternatively, less toxic or non-toxic materials such as extracts of plant materials or inert dusts. Improved agro-processing techniques provide producers with an opportunity for adding value to their produce, whilst reducing the drudgery of manual processing. A considerable amount of research has been devoted to developing technologies aimed at improving the efficiency of the post-harvest system but such technologies have not always been taken up. A precondition of technology transfer and adoption is that the technology must be appropriate to the potential adopter. Farmers and extension personnel must be involved at the centre of the technology development and testing process. Involvement and interaction of farmers and extension personnel at this stage are likely to result in greater uptake of new technologies. Farmers can provide feedback on development of interventions and extension personnel will be better able to analyse farmers' post-harvest problems and identify technology options suited to farmers' individual circumstances.

INTRODUCTION

Maize is the world's most widely grown cereal crop and it is an important staple food grain in many African countries. Maize production in Sub-Saharan Africa is estimated to have been increasing between 2% and 3% annually over the last 25 years, but it is questionable whether this current rate of increase can keep up with demand since the population of the region is projected to double in the next 20-25 years. Moreover, it is expected that more than half of the population will be living in urban areas by 2020 (IFPRI, 1997) and the inevitable urban expansion into farming land will further restrict the land available for maize cultivation. Hence, the often repeated calls for greater efforts to be made to improve maize production.

Much research is being devoted to improving productivity of maize through the development of new, higher yielding varieties. Among these are the varieties of quality protein maize (QPM) which not only show supe-

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rior yields of 10% or more over normal commercial varieties of maize, but also provide a means of improving the nutrition for resource poor producers and consumers.

However, in order to maximise the benefits of this improved production, attention must also be paid to improving the capabilities for post-harvest handling, storage and processing of maize in order to reduce losses and to maintain quality. It is widely acknowledged that losses of maize after harvest can be substantial and often these loss levels often have been used to justify efforts to increase production. However, the pressures of increasing production mean that it is more efficient to preserve what has been produced rather than to produce more to compensate for what might be lost after harvest.

Post-harvest consequences of the introduction of high yielding varieties of maize

In Africa, it is estimated that between 60% and 75% of all grain production is retained at the farm level, perhaps mainly for home consumption but also for sale and for seed. The methods of storage have evolved over many years of experience and tradition and are usually well suited to local conditions. Nevertheless, stored grain is subject to various degrees of loss and deterioration due to attack by moulds, rodents, birds and especially insects. Experience from a wide range of loss assessment studies show that in the truly traditional storage system, losses are usually well contained at around 5% (Tyler and Boxall, 1984). However, because of the many technical, social, economic and political changes that have taken place, that truly traditional system probably no longer exists and farmers now face considerable problems in post-harvest management of grains.

The spectacular increases in yield brought about by the introduction of high-yielding varieties often place a severe strain on the traditional post-harvest system. Not only are farmers faced with having to handle, store and process much larger quantities of grain but also they frequently find that the grain is more vulnerable to attack by storage insect pests. The inherent qualities of traditional maize varieties (namely hard endosperm and good husk cover) help to protect the grain from insect attack, and will have been selected, over time, for their good storage characteristics. The high yielding varieties (including QPM) although possessing improved nutritional value, unfortunately have some characteristics that render them liable to spoilage during storage. Where the husk does not extend sufficiently to cover all the grain on the cob there is a risk of damage through entry of moulds and insect pests and the larger grains of these varieties are softer and extremely susceptible to insect attack.

The fact that plant breeders have not incorporated good storage characteristics in the selection of new varieties often surprises many people. But this is not an oversight - if a commodity is unattractive to insects it may also be unattractive to humans, maybe because of taste or flavour, or because small hard grains, which may deter insects, are also difficult to process. Breeders have many factors to consider both post- and pre- harvest. There is the pressing need for higher yields, the need for drought resistance, improved nutritional value and of course, the consumers' preferences must be taken into consideration.

Hence, the breeder may ask, quite justifiably, 'why try to incorporate post-harvest pest resistance factors when good control can be achieved by use of pesticides?' (Interestingly, there is now more interest in breeding varieties of QPM that are resistant to storage pests. For example, CIMMYT's research project 'Genetic approaches to reducing post-harvest losses' aims to develop maize lines resistant to the important pests *Prostephanus truncatus* and *Sitophilus zeamais).*

Unfortunately, storage pesticides have not always been readily available and at an acceptable price. The farmers' typical response in the absence of a suitable technology to reduce losses has often been to grow local varieties which store well for their own use, and to produce the high yielding varieties for sale at, or very soon after, harvest. This may have been an attractive proposition while there were marketing boards to guarantee a high floor price at harvest. However, the various economic and political changes that have taken place throughout Africa have tended to make on-farm storage more important than ever.

The introduction of liberalised agricultural markets has created advantages and disadvantages for grain producers. There is now greater opportunity for speculative storage. However, whilst the storage of marketable surpluses may be attractive to those willing and able to invest in technology to minimise losses to pests, others may simply be forced to retain more grain for longer periods at the farm level, with an increased risk of loss. Where the risk is particularly high as in the case of high yielding varieties, a common coping strategy is to sell grain early, often very soon after harvest, to avoid high losses to insects, and then to buy grain later (but at higher price) as it is required (Boxall 1998). Clearly, if such farmers (usually the poorer, small-scale producers) are to reap the benefits of producing high yielding QPM varieties they must receive sufficient support to enable them to be confident that they can store the grain satisfactorily.

Maize storage

Maize may be stored in a variety of ways. For example, on the cob (with or without husks) on racks or in cribs, or as shelled grain in bags, pots, baskets, or mud brick bins. These traditional structures provide many features that are conducive to safe storage and, since the stores are constructed of local materials, they are relatively inexpensive. Nevertheless, there is often room for improvement, especially where there are now shortages of the traditional store construction materials or where construction skills have been lost.

Approaches to improving farm storage systems have been either:

a) to make minor modifications to the traditional store, usually to guard against moisture uptake or to provide barriers against rodents rather than to deter insect pests; or,

b) to introduce a new store using industrially produced materials and one that will provide a barrier against moisture, rodents, insects;

although, in both cases, it has also been usual to promote the use of pesticides to combat storage insect pests.

However, neither of these approaches is as simple as they may first appear. Technically sound improvements to traditional stores may be socially unacceptable, or simply too costly. The same may apply to newly introduced systems. Many designs of small, closed storage bin, constructed from wood, brick, concrete or metal may appear attractive especially if they can be made gas-tight, thereby allowing good control of insects by fumigation. However, it is evident that uptake of such improved stores has often been poor because of high costs, inadequate supplies of materials, lack of construction skills, or the need for extra drying of the crop for safe storage in closed systems.

Even when an improved system has demonstrable technical and economic advantages, farmers may still be unwilling to adopt it. They may see little point in changing their store until the existing structure requires repair or replacement. On the other hand, institutions promoting the new system may have to address issues such as the production and distribution of storage structures, or the provision of credit to finance the schemes.

Pesticides

Pesticides are often regarded as the most successful of storage technologies; they are considered as being attractive to farmers because they fit well with the range of storage systems and require little effort to apply and little capital investment. They can be highly cost effective, with the value of the grain saved being anything from 10 to 25 times the cost of the insecticide.

Why then are serious losses in farm-stored grain still reported? Maybe the use of insecticides does not fit well with the storage system after all. For example, where maize is traditionally stored on the cob, labour constraints, the lack of appropriate containers for shelled grain and of storage space, may discourage farmers from shelling until the grain is to be consumed or sold, or until infestation becomes obvious.

It is often assumed that farmers can obtain insecticides of the correct formulation, in appropriate packages, at the right time, and at or close to the farm-gate and that expert advice on the use of chemicals is available. This may have been so where governments were involved in input supply and provision of advice via the extension services, but the introduction of economic reform programmes have tended to restrict public sector budgets with the result that such services have been suspended or at best severely reduced. Adequate and timely supply of insecticides coupled with expert advice is essential to ensure correct and safe application and to discourage farmers from using inappropriate and potentially dangerous products such as pesticides designated for use against field pests.

However, there is increasing concern over the use of conventional synthetic insecticides on health and environmental grounds. The high toxicity, persistence and wide spectrum of activity of some compounds has already led to the withdrawal of certain insecticides and farmers and traders are often reluctant to accept the admixture of insecticides with food grains. These concerns have highlighted the need to find ways of either reducing the amount of insecticide needed to treat stored grain and to identify alternative compounds.

Insecticide use might be reduced by dividing the harvest into two parts before storage and treating just the one part that will be kept for a long period. The second part to be stored separately remains untreated and is used first. The size of the two parts can be determined by reference to the economic damage threshold (Henckes, 1994). In Ghana, reduced levels of insecticide have been used successfully to protect maize stored in traditional granaries against attack by storage insects such as *P. truncatus* and *Sitophilus* spp. Since the initial infestation tends to occur towards the base of the store, insecticide need only be applied to the basal layers of grain. A high degree of protection has been reported in mud silos and traditional cob-storage structures even when pesticide application is reduced by 50% and 80% respectively (Birkinshaw and Hodges, 2000).

Farmers have traditionally used a variety of local materials with insecticidal properties such as plant products and minerals, (ash, sand, lime). They may not provide complete control but can reduce infestation to low levels that are considered economically worthwhile.

Of the wide range of plant materials used as grain protectants the most promising and popular is neem (*Azadirachata indica*), studies of which have been extensive. The insecticidal properties of neem are well known to farmers in many parts of the world and some neem extracts and derivatives have even been commercially produced and registered as insecticides. Other promising plant materials include sweet flag (*Acorus calamus*), wormseed (*Chenopodium ambrosioides*) and pepper (*Piper* spp) (Golob *et al.,* 1999). Recent studies in Ghana identified seventeen different plant species used as storage protectants, eight of which were very commonly used. Farmers favourably rated the use of these materials in comparison to synthetic insecticides when assessed against criteria such as cost, effectiveness, availability, toxicity, ease of use, acceptability and versatility. Trials on screening of candidate plants through laboratory and field trials, and toxicity testing are continuing to allow recommendations to be formulated on which materials might be used at farm-level and/or require further research (Belmain, 1999; Belmain *et al.,* 1999).

Minerals, such as sand, lime, and ash can be applied to grain to form a physical barrier to insects, but large quantities are needed, perhaps 10g/kg of grain or even up to 50% by weight of grain to be treated.

Some dusts, such as diatomaceous earths have been commercially available for many years. They have extremely low toxicity to mammals and are commonly used to combat internal parasites of cattle and poultry. Diatomaceous earths are now registered in several countries as grain protectants although there is little information about their efficacy in tropical small-scale farm storage. When used as a grain protectant, the inert, sorptive or desiccant dust disrupts the waxy cuticle of insects, which permits loss of body fluids leading to dehydration and death. Recent field trials in Zimbabwe have demonstrated the value of diatomaceous earths as an alternative grain protectant to organophosphate insecticides for sorghum, cowpeas and maize. Diatomaceous earths were equally as effective as the conventional insecticide in maintaining damage levels at a very low level over a period of 40 weeks (Stathers, 2000).

Processing

Agro-processing provides an opportunity

for producers to add value to their crop and the introduction of good processing technologies alongside the introduction of QPM varieties can encourage their wider adoption, reduce post-harvest losses, reduce the drudgery of manual processing, and improve quality and productivity.

Most traditional post-harvest operations are slow and may be a constraint to the wider cultivation of high yielding varieties of QPM. For example, maize is traditionally shelled by hand, by beating cobs with sticks or using small hand shellers, thus, available labour may not be sufficient to cope with increased yields. The high labour requirement for shelling was identified as a factor limiting the area given over to maize cultivation in Zambia; producers with access to mechanical shellers commonly had larger areas of land under maize cultivation (Boxall, 1997). Not only can mechanical shellers increase productivity they can also reduce post-harvest losses and lead to improved quality. Although some breakage or cracking of grains may occur during mechanical shelling, the quality of the maize is usually superior to that of hand-beaten maize. Increased incomes are therefore possible because of a lower rejection rate by traders due to poor quality (broken) maize.

In most African countries women are responsible for food processing. Since whole grains store better than ground flour many rural women grind or pound small quantities of grain daily for home consumption. The methods are often tiring, monotonous and time consuming. Some women will have access to small custom or co-operatively owned power driven mills and although this can reduce the drudgery of home processing, it may involve travelling long distances and/or long waiting times at the mill, especially when the volume of maize production increases.

The International Institute of Tropical Agriculture (IITA) in collaboration with the Sasakawa Africa Association (SAA) has been addressing the issue of village-level agro-processing and a whole range equipment, including machinery for maize shelling and processing, which has been produced (Jeon and Halos-Kim, 1998).

Technology transfer

Clearly there is a considerable body of research world-wide devoted to developing technologies aimed at the reduction of qualitative and quantitative losses in storage and of improving the efficiency of the post-harvest system. However, closer examination of the outputs of this research often shows that the technologies are not always taken up.

There is widespread evidence of recommended practices or techniques being ignored and equipment not being adopted. Looking at some of the past attempts to reduce grain storage losses in Africa, for example, we find numerous concrete, brick and metal structures that are no longer in use. In the field of post-harvest processing, equipment aimed at relieving the drudgery of women may be found lying idle because the items are culturally unacceptable or do not fit with the users' needs.

A precondition of technology transfer and adoption is that the technology must be appropriate to the potential adopter, i.e. adopting the innovation will be in his/her best self-interest. If this precondition is not met, any initial adoption may be ephemeral. This is particularly so in cases where a new technology is promoted with the assistance of subsidies or credit. All may go well in the early stages, but a subsequent loss of interest by farmers may be attributed to their failure to comply with credit conditions or a lack of effort by extension workers; the fact that the technology was inappropriate being completely overlooked.

The conventional approach to post-harvest technology development and transfer has tended to proceed stepwise as follows:

- researchers at research stations produce a recommended technology;
- extension staff are trained in the application of that technology;
- the technology is passed on to farmers through farmer training programmes or demonstrations.

If the technologies are not adopted, extension workers may be blamed for not doing their job properly or farmers are criticised for being slow to understand the need for change. Only as a last resort may consideration be given to assessment of the appropriateness of interventions to the specific circumstances of the target group. Officially promoted options are usually formulated in packages of recommendations suitable for specific groups of farmers or farming systems.

The recommendations may be technically sound but they may be unavailable, inappropriate, inconvenient or too expensive for some farmers. The majority of farmers will need good information about all the options available to them. For example, a recommended storage package for medium and large-scale farmers producing high-yielding QPM might be:

- dehusk cobs at harvest;
- spray cobs with an approved insecticide;
- store in a narrow ventilated crib;
- shell cobs when dry; and
- mix grain with an approved insecticide and store in sacks or in a storage bin.

Such a package assumes that the farmers are able to plan how they will manage their stored crop right from the start of the season. A few may be able to do this and for them the package of recommendations will be acceptable. However, most farmers, especially small-scale farmers, may adopt only parts of the package or none at all. Farmers tend to make a series of decisions on how to manage their crop in sequence throughout the season based on the options and constraints at each point.

Effective storage programmes that will minimise losses must involve farmers in the analysis of their storage problems and in identifying appropriate storage systems and management techniques. The analysis of storage problems will include an assessment of:

- the post-harvest handling methods and constraints;
- the advantages and disadvantage of traditional and improved storage methods;
- the potential causes, extent and value of storage losses;
- any current loss reduction procedures;
- the reasons for storage and the farmers' future expectations; and
- alternative methods of loss reduction and the costs and benefits.

The role of the extension officer is therefore as a facilitator in the analytical process, the ultimate goal of which is to advise farmers on particular options suitable for their individual circumstances. This participatory approach of involving farmers, either individually or in groups, in deciding on a storage management strategy will be more time consuming and more complex than promoting a single extension message but it is likely to be more effective and will result in a higher adoption rate of recommendations.

When village-level interventions are planned with the objective of reducing the labour of traditional processing, or to provide cash income for individuals or groups, the activity should be viewed in the context of a series of inter-linked systems: the food system, involving production, processing and marketing; an economic system of production and exchange of assets, including labour; and a social system of bargaining and responsibilities within the household and community. Evaluating the situation in this way and involving all stakeholders will make it possible to assess more accurately who will benefit and who might lose from the introduction of the new technology. Village level processing schemes aimed at raising income have sometimes run into marketing problems because of lack of management or marketing expertise and failure to research potential markets adequately.

Farmers are more likely to adopt new technologies if they have been in Certified Involved from the development stage. The involvement of farmers in agricultural research is not a new idea (Biggs, 1989) and indeed on-farm, client-oriented research has been practised, often under the label of farming systems research (FSR) since the mid-1970s (Okali *et al*.,1994). Although there is still a tendency for much research to be centrally organised and focussed at research stations, rather than on the farm, several research organisations now incorporate farmer participatory research into their programmes (Farrington, 1997). Very recently Uganda has adopted a new approach to research and extension aimed at improving the process of technology generation and technology transfer. This is to be achieved through decentralisation of activities, greater participation of potential users, improved utilisation of knowledge found in local communities and involvement of farmers in programme planning and evaluation of decisions about extension provisions (Anon., 2001).

Similar re-orientation is required in post-harvest agro-processing programmes. The Post-harvest Engineering Unit at IITA noted that a number of technologies introduced in Africa since the 1970s had met with little success because they did not fit with users' needs. The unit's technology development approaches have now been re-oriented to fully integrate social, economic and technical considerations. The design and manufacture of equipment, through stakeholder participation, now takes account of factors such as: the pattern of crop production; the type and nature of food processing and consumption; the available resources; the technical and economic capability of farmers; marketing opportunities; special requirements for specific food preparations and taste preferences of consumers (Jeon and Halos-Kim, 1999).

CONCLUSION

The widespread introduction of the new high yielding varieties of quality protein maize can have an enormous impact on increasing food availability throughout Africa.

However, the benefits of the increases in production that are potentially available must be maximised by close attention to improving post-harvest storage and processing. Losses after harvest must be kept to a minimum and maize of a high quality must be delivered to consumers.

Post-harvest systems are highly complex because of the interaction of technical, social and economic constraints. The use of an appropriate and effective research and development and extension approach is the key to ensuring that post-harvest research and technology transfer activities have the desired impact. Research into new ways of reducing post-harvest losses and improving the efficiency of the system will continue, but a wide range of storage and processing technologies already exists. These technologies for farm- and village-level will have varied probabilities of success unless they are developed and introduced on the basis of an understanding of the criteria that farmers use to adopt/reject the technology. There is now an increasing recognition of the fact that farmers need to be at the centre of the technology development/ testing process and more emphasis is being placed on so-called Farmer Participatory Research (FPR). This involves methods designed to give farmers an active role as decision makers in planning and execution; farmers must be encouraged to participate in: problem diagnosis, planning and design, experimentation, adaptation and validation, and, later, in promotion of innovations.

The approach will enable farmers to describe how they perceive the technologies on offer and researchers to understand farmers' points of view. The staff of the extension services also have a crucial role to play. They must be able to present farmers with a choice of options for their particular circumstances and this means that new demands will be made of extension staff, particularly those accustomed to delivering a single message to all farmers. With systematic feedback to technology design and to the farming community, recommendations can be formulated with a knowledge of a greater degree of acceptability.

REFERENCES

Anon. (2001) Uganda - new approaches to agricultural extension. *Feeding the Future* Issue 16. Newsletter of the Sasakawa Africa Association.

Belmain, S.R. (1999) Use of plant materials for protecting farm-stored grain against insect infestation. Final technical report. Project R6501. Chatham, UK. Natural Resources Institute. 33 pages..

Belmain, S.R., Golob, P., Andan, H.F. and **Cobbinah, J.R.** (1999) Ethnobotanicals - Future prospects as post-harvest insecticides. *Agro Food Industry Hi-tech*. **10** (5): 34-36.

Biggs, S.D. (1989) Resource-Poor Farmer Participation in Research: A Synthesis of Experiences from Nine National Agricultural Research Systems. OFCOR Series No. 3 (Comparative Study) ISNAR. The Hague. 58 pages.

Birkinshaw, L and **Hodges, R.** (2000) Improving IPM approaches for LGB control in Africa. *PhAction News* No.3.

Boxall, R. A. (editor) (1997) *Constraints analysis of the post-production sector in Zambia.* Project: PFL/ZAM/003/PFL, Final Report. Rome, Food and Agriculture Organization of the United Nations.

Boxall, R. A. (1998) *Grains post-harvest loss assessment in Ethiopia. Final report.* NRI Report No.2377. Chatham, UK. Natural Resources Institute. 44 pages.

Farrington, J. (1997) Farmers' Participation in Agricultural Research and Extension: Lessons from the last decade. *Biotechnology and Development Monitor*, No. 30, p. 12-15.

Golob, P., Moss, C. Dales, M., Fidgen, A.,

Evans, J. and **Gudrus, I.** (1999) The use of Spices and Medicinals as Bioactive Protectants for Grains. FAO Agricultural Services Bulletin No. 137. Rome. Food and Agriculture Organization of the United Nations.

Henckes, C. (1994) Dividing the harvest: an approach to integrated pest management in family stores in Africa. pp. 925-928 in: *Proceedings of the sixth International Working Conference on Stored-product Protection*. Highley, E.; Wright, E.J.; Banks, H.J. and Champ, B.R. (eds.). Canberra, Australia

IFPRI (1997) *Achieving food security in southern Africa*. Haddad, L., ed. IFPRI, Washington D.C.

Jeon, Y.W. and **Halos-Kim, L**. (1999). *Characterizing the desirability of post-harvest technologies for African conditions.* In Kwarteng, Joseph, ed. 1999. *Enhancing post-harvest technology generation and dissemination in Africa.* Mexico City: Sasakawa Africa Association. 79 pages.

Okali, C., Sumberg, J. and **Farrington, J.** (1994) *Farmer participatory research: rhetoric and reality*. London, UK: Intermediate Technology Publications and Overseas Development Institute. 156 pages.

Stathers, T. (2000) Use of diatomaceous earths in tropical small-scale grain storage. *PhAction News*. No 2.

Tyler, P. and **Boxall, R.A.** (1984) Post-harvest loss reduction programmes: a decade of activities:- what consequences? *Tropical Stored Products Information* **50**, 4-13.

THE GENETICS OF QUALITY PROTEIN MAIZE

Ernest W. Sprague

A single recessive gene, Opaque 2, controls tee improved protein quality in QPM maize. In spite of this it took about 20 years of research to develop QPM varieties and hybrids that were agronomically acceptable. Why?

Historical Review

I would like to review the development from the discovery of opaque 2 to the production of QPM.

The opaque 2 mutant was found in genetic stocks that had been classified in the 1930s. It was labelled opaque 2 after the recessive gene, which gave the kernels an opaque appearance, in contrast to the normal translucent shiny appearance of regular dent and flint kemels.

In 1964 Purdue University reported that a mutant maize that was homozygous for the opaque 2 gene contained nearly twice as much lysine and tryptophan in the endosperm as normal flint and dent maize. In addition they found that laboratory rats fed opaque 2 maize gained weight much more rapidly than did the rats fed normal dent maize.

This discovery came before IRRI rice and CIMMYT wheat had any impact on worldwide food production. There was a large-scale shortage of food in much of the world, and the@. threat of malnutrition and even famine was of great concern. The lack of protein in the diet of many people in the developing world was also a major cause for concern. Because maize was then and is now the main staple in the diets of millions of people in the developing world, crop researchers and nutritionists saw opaque 2 maize as a promising candidate for reducing wide spread protein deficiency.

This potential stimulated many maize research programs worldwide to devote efforts to introduce the opaque 2 gene into their maize breeding programs.

This effort was endorsed when feeding trials with pigs and chickens demonstrated that opaque 2 maize was very much superior to normal maize as feed. This further fueled more enthusiasm. Even more dramatic and exciting was the rapid recovery seen in children who were just short of dying, after opaque 2 maize was substituted for normal maize in their diets'.

Maize breeders were stimulated to initiate breeding programs to incorporate the opaque 2 gene into agronomically good normal material as soon as possible. From 1964, the year that the biochemical effects of opaque 2 were discovered until 1970 the major emphasis in maize breeding was to obtain opaque 2 versions of normal maize genotypes, principally using the classical backcross system.

During this initial effort, several opaque 2 varieties and hybrids were developed. Some of these were promoted for commercial production in several countries in the early 1970s. However, in the rush to get the advantage of increased protein quality to market, sufficient care was not taken to develop agronomically desirable materials and they suffered a major set back due to the lack of competitive performance with their normal counterparts. Enthusiasm and interest began to decline gradually. By the mid 1970s the initial excitement was overshadowed by disappointment and frustration. Many breeding programs drastically reduced research efforts on quality protein and others abandoned work on protein altogether.

Because of the potential benefits of the end product, at CIMMYT we decided to continue research on quality protein at the same pace, in an effort to define and overcome the problems that were limiting opaque 2 from being competitive at the production level.

In 1970 CIMMYT initiated an intensive and large-scale effort to breed superior agronomic genotypes combined with high-quality protein characteristics. The major emphasis was placed on converting normal maize genotypes, from tropical, sub-tropical, temperate and highland populations, to opaque 2 with its associated soft chalky endosperm. This work continued for five years, and the agronomic quality of the converted material was as good as the non-opaque 2 donors.

International testing of the converted material illustrated that although these materials were agronomically acceptable, there were key problems, that acted as major obstacles to the acceptance and promotion of the materials. These problems were reduced grain yield in the order of 10- *1* 5%, unacceptable kernel appearance due to dull soft chalky endosperm, which gave greater vulnerability to rot organisms, more damage by weevils during storage and slower drying follow physiological maturity of the grain.

At this stage it was obvious to us that a different strategy was now required. The approach that appeared to be the most promising to remedy the problems encountered involved the accumulation and exploitation of genetic modifiers of the opaque 2 locus. The successive accumulation of the desired modifiers increased the hardness of the kernel thereby reducing the undesirable opaque appearance and associated problems, while the grain maintained the high protein quality.

In 1974 CIMMYT research on quality protein switched over to this new breeding strategy and the breeding effort on quality protein became a parallel and integral part of CIMMYT's regular maize improvement program. The new strategy involved the use of two genetics systems: a simple system involving the opaque 2 gene to improve protein quality and a more complex polygenic controlled system to remedy the undesirable side effects of the opaque 2 system.

To maximize our efficiency we decided to concentrate on a limited number of populations that represented the most widely and frequently used genotypes in the tropics and sub-tropics. This new approach necessitated the development of donor stocks of populations that carried the opaque 2 gene, and therefore possessed the desired protein quality, with the necessary modifier genes, which gave hard and vitreous endosperm to the kernels. By the end of three years we had established, the fact that modifier genes existed and could be accumulated to provide kernels that looked like normal kernels with equal kernel weight to normal kernels.

During those three years we had to over come several negative factors. We found that some modifier genes gave an undesirable appearance to the kernel; others gave cars with open kernel rows and still others gave kernels with a tendency to pop or split. After several cycles of selection, however, it was possible to eliminate these negative and undesirable traits. Thanks to our ability to do two cycles of selection a year we could speed up this process.

During all these years of work with quality protein we had the services of a first class cereal chemistry laboratory that did chemical analysis on our selections each cycle. Once we had developed material that had hard and vitreous kernels we could no longer rely on the physical appearance of the kernels to indicate the presence of protein quality. It was therefore absolutely necessary to rely on laboratory analysis after each harvest to verify the protein quality of our selections.

Eventually CIMMYT had produced four tropical and three sub-tropical gene pools that had the desired protein quality, the hard desirable endosperm, good agronomic characters and yield ability equal to normal counterparts. These pools served several important functions. They formed excellent donor stocks to convert normal maize genotypes to opaque 2 quality protein. Superior fractions could be extracted and introgressed into appropriate opaque 2 populations for continuous improvement. They were source materials that were provided to cooperating national programs, and they provided new populations for the international testing program.

Despite the successful conversions we found that the name opaque 2, even with a hard endosperm carried a stigma because the original opaque 2 kernels were opaque and had associated problems. To get away from this negative stigma we changed the name of our desirable materials to Quality Protein Maize (QPM).

Role of QPM in Nutrition

While the breeding efforts had proved successful, there had been a reversal in the scientific opinion on the role of protein in the alleviation of malnutrition.

Before 1970 most nutritionists had viewed malnutrition in developing countries primarily as a problem of protein deficiency, and that produced symptoms of the disease known as Kwashiorkor. Children with Kwashiorkor symptoms were a common sight before 1970 and are common in many communities in Africa today. Because maize is a staple crop in these communities, QPM could provide great health benefits. If protein deficiency were the problem, QPM maize could be substituted for the normal maize that these children consume, and the symptoms of protein malnutrition could be alleviated and even eliminated.

However, in 1973 a report from the United Nations (FAO/WHO) dramatically lowered the previous protein requirement figures recommended in human diets. Soon strongly worded papers appeared condemning the focus on protein. They claimed that 'malnutrition was due to lack of calories and not to a lack of protein. Many leading nutritionists supported the view that Marasmur, extreme energy deficiency, rather than Kwashiorkor was really the main problem of global malnutrition.

This view greatly diminished the perceived role of QPM in the alleviation of malnutrition. Interest in QPM declined and many research institutions eliminated QPM from their research agenda. Having observed the results of experiments which compared QPM with non-QPM maize in diets of chickens, pigs and children; all of which showed the great benefits of QPM, CIMMYT adhered to its view that protein was of prime importance, and continued its effort with QPM.

The argument over calories versus protein continued into the late 1980s. Then, in 1987 three nutritionists Vemon Young, Dennis M. Mier and Peter L. Pellett stated that FAO/ WHO had been wrong. They came to the conclusion that the requirements for lysine, leucine, valine and theonine are probably two to three times higher than the figures recommended in 1985. They also concluded that lysine is a limiting factor in diets characteristic of a number of countries such as Nigeria, Guatemala and Ghana. Thege are major maize producing countries, where QPM could be a prime supplier of increased protein in the people's diets, . and there are many other maize producing countries that use very similar diets.

Changing Strategy of QPM

In 1988 a panel representing the U.S. National Research Council published the results of its review of CIMMYT's QPM program. They recommended that it was time to move ahead with QPM. In spite of this recommendation, however, and contrary to the better judgment of those scientists working with the crop, in 1991 CIMMYT's administration, together with some Board members decided to stop its QPM research program. This was a disaster for the moral of the QPM researchers and for the immediate future of QPM. Fortunately the QPM genetic material was put in cold storage and made available to any researcher that requested it.

By the time, C~YT stopped its program many QPM varieties and hybrids had been developed by CIMMYT, and by some collaborating national programs. There had been enough field trials and farmer production to eliminate any concern about the competitive productivity of QPM in many different genetic backgrounds. ("- materials were-fully competitive in all aspects with normal maize.

Several national programs, Brazil, China, Guatemala and Ghana for example continued research with QPM and continued to develop varieties and hybrids.

In 1989 SG 2000 held a review seminar in Ghana. Dr Norman Borlaug, Mr. Ryoichi Sasakawa and President Jimmy Carter took the opportunity to introduce the concept of QPM as a nutritious food to the president of Ghana, despite the continuing debate in Ghana and elsewhere over the relevance and usefulness of QPM. After much deliberation by the various stakeholders Ghana decided to move ahead with an intensified research program on QPM. They received technical and financial assistance and encouragement from SG 2000, the CIMMYT resident scientist and from the Associate Director of the CIMMYT maize program.

In 1994 an international symposium on QPM was held in Brazil. SG 2000 sponsored African scientists that were working on QPM to attend the symposium. This, together with a change in the political environment, influenced CIMMYT to seek funds to reestablish its QPM program. They were very fortunate to receive a grant from the Nipon Foundation that would support research on QPM for five years.

Since this time they have resumed their work on QPM population and hybrid development, and with collaborating countries, have identified outstanding QPM hybrids that have often shown a yield advantage of one to ' n or more per hectare over the best normal maize hybrids. They have supported research in other countries and trained world scientists in techniques of breeding and seed production. Perhaps the best indicator of their success is that last year they received 180 requests for QPM seed, and shipments were made to 29 countries. The initial grant term is about to end and CIMMYT is seeking funding for a further five years.

Today there is an adequate range of genotypes with quality protein to meet the germplasm needs of most if not all of the environments of the world. With the wealth of gennplasm available to maize breeders worldwide it is possible and necessary to vigorously develop and promote QPM varieties and hybrids. In Africa, the immediate effort should go into the improvement of yield and the development of streak and striga resistant material. As this is accomplished, other limiting factors can be identified and pursued.

Seed Production

The method of seed production used for a crop depends on its breeding system and the genetics of the characters involved. Maize is a cross-pollinated crop, and as 1 have mentioned, the quality of the protein in QPM is controlled by a single recessive gene. The physical quality of the endosperm is controlled by a complex system involving many modifying genes.

To maintain the protein quality and any character controlled by a single recessive gene, great care should be taken to isolate the seed field from contaminant normal maize Every kernel that is the product of a pollen grain from a normal maize plant will be heterozegous for the opaque 2 gene and therefore have no enhanced protein quality. This is, because the kernel must be homozygous to produce this protein.

Because several genes control the physical quality of the endosperm. it would not be as drastically affected by contaminant pollen. However the standard required for seed production should be appropriate for the character that would be most affected by contamination.

This is especially important for seed production of the inbred lines that are the parental material. In hybrid seed production, contamination of one of the inbred parents will result in a number of heterozygous plants in that line. If used as the female line these heterozygous plants will produce normal gametes. These normal female gametes will be pollinated by opaque 2 pollen and produce heterozygous plants that will be sold for food production. In the farmers field the heterozygous plants will produce 25% opaque 2 kernels and 75% normal kemels.

For open pollinated varieties also, to possess the desired protein quality, precaution must be taken to eliminate contamination throughout the seed production process. To illustrate: if one percent contamination takes place in the breeder seed production then one Kg (equivalent to seed which will produce 3000 plants) per 100 kg of seed will be heterozygous for protein quality. That one kg will not express any visual signs that will distinguish it from the other 99 kg of seed. The 100 kg will plant 5 hectares for foundation seed production of which 3000 plants will be heterozygous and distributed at random through the 5 hectares. One half of the pollen shed from the 3000 contaminated plants will be normal pollen and one half will be opaque 2 pollen. Each of the normal pollen grains that fertilize an opaque 2 female gamete will result in a kernel that is heterozygous for the opaque 2 gene and therefore be normal for protein quality. Also remember that one half of the female gametes produced by the 3000 heterozygous plants will also be normal and when fertilized with opaque 2 pollen will produce a kernel that is heterozygous. The female gametes that are normal will, when fertilized by a normal pollen grain, produce a kernel that will be homozygous normal. None of these kernels will have the desired protein quality.

In many if not most situations farmers will save their own seeds share with their neighbours. It is easy to visualize how a small amount of con the breeder seed level will result in a very diluted and badly contaminated QPM in just a few years.

Since this contamination cannot be seen with the naked eye, there is no way that the fanner can know that he is planting seed that is inferior with regard to protein quality. therefore the responsibility for pure seed falls back on the seed producer at each level or stage of seed production.

The Importance of Genetic Purity

Genetic purity is important because those kernels contaminated with normal germplasm will not have the desired protein quality, and it is this protein quality that is the very essence of QPM.

The quality of the opaque 2 protein is almost as good (90%) as skimmed milk. This is what makes the difference in the human diet and **is** particularly advantageous. for the development of children. This is what will make swine and poultry gain more weight per unit time and is so desirable to the industry.

Five tons of QPM maize per hectare with its 1 0% protein of superior quality will give 500 kgs of protein equal to 450 kgs of milk protein. The infusion of this quality protein into the human diet will have a very positive effect on the health of the population and in generating income in the poultry and swine industry.

When farmers see the results of feeding QPM over regular maize they will demand QPM in preference to regular maize. Farmers will not see a difference between contaminated QPM and regular maize. There will be no difference. They will be cheated out of the very significant benefits of QPM.

1 cannot emphasize enough that the genetics of QPM necessitates its purity. We must give the farmer what he deserves and take all precautions to guard against contamination.

As 1 have already mentioned, because QPM kernels cannot be identified visually, any breeding program has to rely on laboratory analysis for appropriate selections. It is essential to have a service laboratory that will, on a timely basis analyze the selections for protein quality to make sure that as other characters are improved the value of the protein is maintained. The importance of chemical analysis applies to seed production also. Every producer of QPM seed should have access to a laboratory that will check the quality of the protein at each step of the seed production process.

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