MALAWI MAIZE IMPROVEMENT AND PRODUCTION RESEARCH ACTION PLAN
1989-1999
(Revised March 1991)

L. D. M. NGWIRA, B. T. ZAMBEZI, W. G. NHLANE,
E. M. SIBALE AND P. NGWIRA.

CHITEDZE AGRICULTURAL RESEARCH STATION
P. O. BOX 158
LILONGWE
MALAWI.

This plan was worked out with a help from CIMMYT, Harare.
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INTRODUCTION

Maize is the most important food crop in Malawi. It is commonly grown throughout the country, especially by smallholder farmers. This cereal is the staple food and major source of carbohydrates for over 80% of the Malawian population. Approximately 70% of the cultivated area of customary land is planted to maize each year. About 1,190,000 hectares of maize are planted by smallholder farmers every year, with a grain production of 1,290,000 tonnes. An additional 10% (approximately 130,000 tonnes) is produced by the estate sector.

In Malawi maize is grown over a wide range of climatic conditions such as altitudes, temperature, rainfall and soil types. It is grown from under 100m to over 1,700m above sea level (asl). However, the main growing areas lie within 600m to 1,300m asl. These plateau areas have the most favourable conditions for maize growth. Outside this range, conditions are considered marginal for maize production mainly due to the short rainy season, which is mostly unreliable, high temperatures (low altitude areas like the lakeshore and Shire Valley) and cool temperatures with overcast conditions (high altitude areas like Dedza Hills, Misuku Hills, Viphya Plateau, Dowa Hills, etc).

Most of the maize grown by smallholder farmers is of the unimproved local flint type which is of low yield potential, tall and late maturing. It is estimated that 93% of the maize crop grown in Malawi, is of the unimproved local types and only 7% is of the improved types consisting of 1.7% composites and 5.3% hybrids. This is a very low statistic considering that promotion of hybrids and composites was intensified in 1978, when the country started its own hybrid seed production through the National Seed Company of Malawi (NSCM). The statistic for improved open pollinated varieties (composites) also does not include areas planted to recycled seed.
The population of Malawi in 1987 was 7.9 million and it is estimated that in 25 years time, the population will reach 16-18 million. Malawi, therefore, needs to develop its economy fast enough to be able to support the fast growing population. Since the economy of Malawi is agriculturally based, economic growth can only be achieved through increased agricultural productivity. The country needs to increase its food (maize) production at a faster rate than population growth to be able to feed its people in future and maintain a healthy economy. This entails increasing maize yields per unit area of land rather than increasing land area put to maize cultivation. There is also an urgent need to release some land under maize for cash crops. At present the national average yield of Maize in Malawi is 1.08 t ha⁻¹.

For Malawi to achieve its objective of attaining and maintaining food self sufficiency, the country needs to increase maize production. To do this, the country needs a very strong multi-disciplinary maize research team to breed high yielding maize varieties, resistant/tolerant to common disease/pests and with acceptable grain quality for good storage and processing. The team also needs to develop, through research, new production technologies (types and rates of inorganic and organic fertilizers, mechanical and chemical weed control, methods of land preparation, intercropping, etc), which are economically feasible under smallholder conditions.

Varietal development will involve strong linkage between breeders, pathologists, entomologists and agronomists. Development of new technologies to go with the new high yielding varieties will need strong linkage between agronomists and economists. This Maize Action Plan encompasses maize breeding, maize pathology, entomology and maize agronomy/economics. Detailed action plans, equipment required, human resource requirements/development, budgets and
expected benefits are presented under each section. The maize team is writing this proposed action plan for funding for four reasons:

1. For the first time a full team (3 breeders, a pathologist and an agronomist) is in place after advanced training. This will make the much needed impact on technology development.

2. There is a pressing need to develop flint (hard endosperm) hybrids for smallholder production.

3. There is an urgent need to generate production packages (e.g. fertilizer rates, weed control methods, intercropping systems, etc) that are economical for smallholder farmers to adopt in all the agro-ecological areas of the country.

4. There is need for a verifiable Maize Research Plan for continuity.
1. CONSTRAINTS TO MAIZE PRODUCTION

Although the maize commodity team has done research work over the past 39 years that has led to the recommendation of new hybrids, composites and synthetics (including LH11, SR52, R201, MH12, MH13, MH14, MH15, MH16, NSCM41, SV17, SV28, SV37, UCA, CCA and Tuxpeno), maize yields have remained low under smallholder management.

The factors limiting maize yields in Malawi include:
1. Low soil fertility
2. Environmental limitations e.g. poor rainfall, heat and water stress.
3. Preference for semi-flint (hard endosperm) varieties as opposed to high yielding dent varieties.
4. Poor agronomic and cultural practices.
5. Pests and diseases such as stem borers, termites, maize streak virus, Puccinia spp. and Helminthosporium spp.
2. RESEARCH OBJECTIVES

The objectives of the maize commodity research team include:

1. To maintain, improve and manipulate breeding stocks with the aim of producing higher yielding varieties of white seeded maize with as much resistance as possible to maize streak virus, *Puccinia polysora*, *P. sorghi*, *Helminthosporium turcicum* and *H. maydis*.

2. To develop and maintain a germplasm bank with materials of diverse origin to be used for composite development as well as isolation of inbred lines.

3. To develop high yielding white flint and dent hybrids, composites and synthetics.

4. To develop varieties tolerant to drought and heat stress for stable yields in drought prone areas.

5. To collaborate with foreign institutions and international research centres working on maize such as CIMMYT, IITA, SARCCUS, etc.

6. To maintain and multiply breeder seed of inbred lines and composites for supplying to the NSCM for large scale seed production.

7. To investigate the response of recommended as well as promising maize varieties to fertilizers and plant densities in all parts of the country.

8. To investigate the use of farmyard manure, crop residues, compost, etc to supplement inorganic fertilizers.
9. To develop low cost and effective weed control methods including screening of herbicides.

10. To determine the optimum time of planting new maize varieties in different agro-ecological zones of the country.

11. To develop maize based intercropping systems.
3. MAIZE BREEDING

3.1 Population improvement

3.1.1 Background

Population improvement per se and hybrid breeding were the two main activities in the maize breeding section during the last ten years. Population improvement was done with the objective of improving open pollinated varieties for use by smallholder farmers who grow maize for home consumption. It was hoped that the improved varieties would replace the low yielding local maize. Since these improved open pollinated varieties were intended for the subsistence farmer, effort was made to make the grain characteristic comparable to that of the local maize in pounding as well as storage qualities.

Several populations have been developed, improved and released to farmers since 1970. These include:

(a) Chitedze Composite A (CCA).
   This population was developed mainly from local germplasm the target ecology being the lakeshore and other marginal areas (below 600m asl).

(b) Ukiriguru Composite A (UCA).
   This was an introduction from East Africa (Tanzania). The target ecology was the mid-altitude ecology (600-1300m asl).

(c) Tuxpeno I.
   An introduction from CIMMYT, Mexico. The target ecology was the drought prone lakeshore area.

(d) Chitedze Composite C (CCC).
   This was developed from CIMMYT and local germplasm to replace UCA which is tall and late maturing. The target ecology is the mid-altitude area. This variety also does well in the lakeshore area.
(e) Chitedze Composite D (CCD).
This was developed from a wide range of early maturing material including some from CIMMYT, East and Southern Africa and local germplasm. It is very early compared to the others mentioned above. It is intended for the Shire Valley where the rainfall cycle is short and erratic and will replace CCA which was the recommended improved variety, for the Shire Valley.

The hybrid programme on the other hand was intended for the commercial farmer, who wanted to grow maize for sale and would sell his crop soon after harvest so that grain characteristic was not of prime importance compared to grain yield. In fact the hybrids so far released to farmers were of the soft endosperm type which requires chemical control against storage pests and have poor pounding qualities (i.e. lower extraction rate of grain on pounding). These include MH12, MH15, MH16 and NSCM41.

The proposed strategy for the breeding programme is to link population improvement with hybrid breeding. This is especially essential with the new emphasis on hard endosperm hybrids. Already, most of the populations available to the programme are of the hard endosperm type and these will provide suitable breeding material for the hybrid programme. Elite inbred lines could be used directly by the hybrid programme.

3.1.2 Future strategy
It is widely accepted that a hybrid breeding programme should be supported by a good, progressive population improvement programme (PIP). It was therefore decided to start a PIP consisting of five populations to support the ongoing hybrid programme.
The populations will be developed for three distinct ecological zones. There will be two heterotic populations for the mid-altitude ecology (MA-A and MA-B). Two heterotic populations for the lakeshore ecology (LS-A and LS-B) and one for the Shire Valley.

The populations will be a mixture of flint and dent materials and will be handled in such a way as to permit the spin-off of early generation lines for the hybrid programmes and improved varieties which will be superior to those presently used by local farmers.

Improvement work on the mid-altitude heterotic populations will be carried out at Chitedze Research Station in Lilongwe, and for the lakeshore and Shire Valley Populations at Chitala Research Station in Salima. There will be some overlapping as it will be possible to utilize some of the earlier maturing lines from the lakeshore populations for development of varieties for use in the Shire Valley. The population for the Shire Valley will be genetically broad based and early maturing. Emphasis will be placed on the improvement of the population for extraction of varieties for direct use by farmers in the area. However, improvement work on the population will be carried out in such a way that inbred lines can be extracted for use in developing hybrids when needed.

3.1.3 Population improvement programme

The population improvement programme is designed specifically to support the ongoing hybrid programme and its new emphasis in producing a wide range of flint and dent hybrids to serve the Malaŵi farmer. The populations will undergo two phases of development:

1. Evaluation of materials from various sources for adaptability. Where necessary crosses will be made to
known sources for desirable characters such as yield, disease resistance and drought tolerance.

2. Division into heterotic populations and the improvement of these populations in a way that early heterotic lines can be selected to be fed into the hybrid programme. This will involve the top crossing of lines in the population to known testers and the recombination of the superior 20-30% of those lines showing good general combining ability (GCA).

3.1.4 **Timetable for the development of mid-altitude populations**

1989 Winter

Top cross locally adapted germplasm and new introductions to testers at Kasinthula and CIMMYT Mazarabani.

1989-90 Summer

1. Evaluate at Chitedze and Chitala top crosses made in 1989 Winter Cycle.

2. Evaluate newly acquired germplasm at appropriate locations.

3. Generate $S_1$'s of the populations involved in top crosses.

1990 Winter

1. Based on the results of the 1989-90 Summer evaluations, advance $S_1$'s of 4 populations which show superior GCA for the two ecological zones representing the two heterotic groups.

2. Top-cross the new introductions evaluated during the 1989-90 Summer cycle to the various testers.

1990-91 Summer
1. Based on the results of the 1989-90 Summer evaluations, advance $S_1$'s of 2 populations for each ecological zone (Mid-altitude and lakeshore) which showed superior GCA to $S_2$, while evaluating for resistance to *H. turcicum*, *P. sorghii* and maize streak virus (MSV) at Chitedze and Harare.

2. Evaluate the population top-crosses from top-crosses made in winter 1990.

3. Make $S_1$'s from the populations which are included in the population top-cross evaluation.

4. Superior flint top-cross hybrids to be yield tested for release to farmers.

**1991 Winter**
1. Top-cross $S_2$ lines made in summer 1990-91.

2. Top-cross new introductions.

**1991-92 Summer**
1. Evaluate $S_2$ top-crosses made in 1991 winter cycle.

2. Advance $S_1$'s from superior introductions to $S_2$ while evaluating for resistance to *H. turcicum*, *P. sorghii* and MSV at Chitedze and Harare.

**1992 Winter**
1. Based on results from $S_2$ top-crosses evaluation, recombine best 10-20% $S_2$ lines from remnant seed using half-sib recombination.

2. Selected $S_2$ lines passed on to the hybrid programmes.

3. Top-cross $S_2$ lines from introductions.
1992-93 Summer
1. Advance the recombined improved cycle to $F_2$.

2. Yield test improved cycle for release to farmers.

3. Evaluate $S_2$ top crosses from introductions.

4. Evaluate new introductions.

1993 Winter
1. Recombine using half-sib selection the $S_2$'s selected based on the results of the 1992-93 test cross evaluation.

2. FORM FLINT AND DENT VARIETIES FROM BEST 10% OF FAMILIES.

1993-94 Summer
1. Advance populations to $F_2$

2. Evaluate new $S_1$'s for diseases (rust, blights and streak) and advance the resistant lines to $S_2$'s.

1994 Winter
1. Self the 4 populations to generate new $S_2$'s.

1994-95 Summer
1. Evaluate $S_1$'s from the 4 populations for resistance to diseases and advance to $S_2$'s.

1995 Winter
1. Top-cross $S_2$'s from the populations and the new introductions to the appropriate testers.

3.1.5 Timetable for the development of lowland populations
1989-90 Summer
1. Yield test flint and dent introductions and local germplasm at Ngabu and Chitala.
2. Select germplasm based on past evaluation of CIMMYT and other variety yield test carried out in the lowland locations.

1990 Winter
1. Recombine the selected materials in dialell crosses at Chitala.

1990-91 Summer
1. Advance to F1 by half-sib recombination at Chitala.
2. Evaluate new introduced germplasm.

1991 Winter
1. Advance to the F2 by half-sib recombination. Include new germplasm identified in 1990-91 Summer as females.

1991-92 Summer
1. Yield test 400-500 HS families.

1992 Winter
1. Self selected 20% of families to form $S_1$'s
2. FORM ELITE VARIETY WITH THE BEST 15-20 FAMILIES BASED ON THE YIELD TEST.

1992-93 Summer
1. Evaluate $S_1$'s for disease resistance ($P.$ polysora, $H.$ maydis and MSV)
2. Yield test the $S_1$'s at Chitala and Ngabu.

1993 Winter
1. Recombine selected $S_1$'s (25-30) using half sib-recombination.
2. FORM EXPERIMENTAL VARIETY USING BEST 15-20 FAMILIES.
3. PASS ELITE S₁'s TO HYBRID PROGRAMME.

1993-94 Summer
1. Self HS families in nursery at Chitala.
2. Evaluate new introductions in appropriate locations.

1994-95 Summer
1. CONTINUE AS FOR SUMMER 1992-93.

3.2 Hybrid programme
3.2.1 Introduction

This programme is divided into two, one for the mid-altitude ecology and the other for the low-altitude (lakeshore) ecology centred at Chitedze and Chitala Agricultural Research Stations, respectively. Each section will be developing both flint and dent single and 3-way cross hybrids. Single-cross hybrids will be used as building blocks for advancing into 3-way hybrids. It is hoped that dent hybrids will still have a place in the country's agriculture, particularly with the estate sector, while the flint hybrids will be aimed at smallholder farmers who can afford some inputs. To date, the best dent hybrids released by the programme include MH12 and MH15 for the mid-altitude and MH16 and NSCM41 for the lakeshore ecology.

To date, work in the mid-altitude hybrid programme has yielded a series of materials, flint and dent, which are at various stages of evaluation. During the 1989/90 summer five single-cross flint hybrids have been evaluated in the national maize variety trials (NMVT). These hybrids will also undergo screening to determine storability and pounding quality. Also ready to be passed to farmers during the 1990/91 season are two top-cross flint hybrids MH12 x Pop 32 and MH16 x Pop 32. These hybrids have already been evaluated by the programme and found to be high yielding and have desirable grain texture.
Seed of the parent (Population 32) will be given to the NSCM during the coming summer cycle for increase.

3.2.2 Timetable for the mid-altitude hybrid programme

1988-89 Summer

1989 Winter
1. Top cross 80 flint/dent inbred lines to the flint tester (AR 154) at Kasinthula Experimental Station.
2. Top cross flint inbreds to testers at CIMMYT Mzarabani.
3. Increase seed of Pop.32 (flint hybrid parent). Crossing of Pop.32 to MH12 and MH16 to produce seed of two flint hybrids for further evaluation by the programme and the NSCM.

1989-90 Summer
1. Evaluation of the test crosses obtained from CIMMYT, Harare.
3. Testing of grain of two flint hybrids (MH12 x Pop.32 and MH16 x Pop.32) for storability and poundability.
4. Evaluation of promising flint top-cross hybrids produced in 88-89 in the NMVT.
5. Screening inbred lines (flint/dent) in the nursery for resistance to *H. turcicum*, *P. sorgi* and MSV.
6. Seed of Pop.32 (flint hybrid parent) delivered to the NSCM for preliminary work on the production of the new flint hybrid.

1990 Winter
1. Test cross $S_3$ lines (flint/dent) received from CIMMYT, Harare. Test cross over 600 flint/dent lines to three tester lines, A, B, AR158 and TZSR-2, A, B and AR158 are dent and TZSR-2 is flint, and has MSV resistance.

2. Release of the two flint top cross hybrids (MH12 x Pop.32) and (MH16 x Pop.32) as MH17 and MH18 respectively.

3. Pounding experiments on MH17 and MH18 indicate extraction percentages (polished grain: unprocessed grain) of 68% for both flint hybrids compared to 55% for MH12 and 72% for local farmers' maize.

1990-91 Summer
1. Evaluate 300 test crosses (flint/dent) made in the winter of 1990.

2. Second cycle of testing of selected promising flint top-crosses developed in winter 1988.

3. NSCM supplies seed of MH17 and MH18 to Agricultural Development Divisions (ADD's) for demonstration plots at residential training centres for farmers.


1991 Winter
1. Make diallel cross of selected flint/dent inbreds.
2. SUBSEQUENT WINTER CYCLES WILL INVOLVE SELFING AND TOP-CROSSING OF INBRED LINES IN THE NURSERIES AT CHITALA AND CHITEDZE.

1991-92 Summer
1. Third year of testing of promising top-cross hybrids developed in the Winter of 1988 for release to farmers.

2. Screening of samples of seed of these hybrids for storage pests and poundability.

1992-93 Summer
1. Third year of testing of top-cross hybrids developed in the winter of 1989.

2. Screening of samples of seed of these hybrid for storage pests and pounding quality.

3. RELEASE OF FLINT TOP-CROSS HYBRIDS TO FARMERS BASED ON THE THIRD YEAR TEST CARRIED OUT IN 91-92.

1993-94 Summer
1. Testing of 3-way and double-cross hybrids developed in the 92/93 season. Testing will continue for a further two summer cycles. By 1996 there should be a series of flint 3-way and double-cross hybrids available for the farming community.

2. RELEASE OF TOP-CROSS HYBRIDS TO FARMERS BASED ON THE THIRD YEAR TEST CARRIED OUT IN 92-93.

1994/95 Summer 1996/97 Summer
1. Further testing of 3-way hybrids (flint/dent) for 3 seasons in NMVT. By 1997 several 3-way hybrids will be made available to farmers.
THE BREEDING PROGRAMME WILL REPEAT ITSELF SUPPLYING A SERIES
OF SINGLE-CROSS HYBRIDS AND LATER THE PRODUCTION OF 3-WAY
HYBRIDS.

3.3 Maize hybrid programme for the marginal areas of
Malawi

1989 Winter
1. Top crossing 80 dent/flint lines to AR 154 at Kasinthula.
2. Produce three-way cross hybrids at Kasinthula.
3. Seed increase of Pop.32 and crossing to MH16.

1989 - 90 Summer
1. First evaluation of 80 top crosses developed in winter 1989.
2. Testing MH16 x Pop.32 for storability and poundability.
   Release of the variety as MH18.
3. Screening lines in the nursery for resistance to H. maydis, P. polysora and maize streak virus at Harare.
4. Top crossing lines from CIMMYT, Harare to "A" and AR 154.
5. Evaluating three-way cross hybrids.
6. Selfing of advancing S_2, S_3, S_4 lines from CIMMYT, Harare.

1990 winter
1. Test across S_3 lines from CIMMYT, Harare at Lifuwu,
   Masenjere and Nkate to AR 154 and "A".
2. Seed increase for trials.

1990-91 Summer

18
1. Promising three-way crosses and top-cross hybrids to be put in NMVT (1st testing).

2. Evaluating over 500 top-crosses/lines from CIMMYT Harare, produced in 1990 winter.

3. Lines of promising three-way cross hybrids to be given to NSCM for production research.

4. Yield testing the best flint/dent top-crosses received from the PIP.

5. Second cycle of testing of the 80 flint/dent top-crosses. Good lines to be given to NSCM.

6. Advance CIMMYT lines by selfing.

7. Diallel crossing of promising lines

1991 winter
Subsequent winter cycles will involve selfing and top-crossing of inbred lines in the nurseries at Chitala, Masenjere, Lifuwu and Nkate.

1991 - 92 summer
1. Second testing of promising three-way crosses and top-crosses in NMVT.

2. Promising top-crosses from CIMMYT and PIP to be put in NMVT.

3. Third cycle of testing of the 80 flint/dent top-crosses. One or two hybrids to be released.

4. Screening of samples of released hybrids for storability, pest susceptibility and poundability.
5. Evaluation of single cross hybrids developed in the diallel in the 1990/91 summer.

1992 - 1993 summer
1. Third testing of three-way cross and top-cross hybrids in NMVT. Release of some hybrids.
2. Best single crosses from diallel to be put in NMVT. At the same time, cross to appropriate testers to produce three-way cross hybrids.

1993-94 summer to 1998-1999 summer
The breeding programme will repeat itself. Supplying a series of single cross hybrids and later the production of three-way cross hybrids.

It is assumed that by 1998/99 summer, four to six three-way flint hybrids will have been released, with acceptable storage, and pounding characteristics.

3.4 Germplasm evaluation
Because of the anticipated large number of hybrids to be developed in the programme the following stages of evaluation will be followed:
1. Hybrid Preliminary Test - 2 locations, 2 replications/location.
2. Hybrid Intermediate Phase test - 4 locations, 2 replications/location.
3. Hybrid Advanced Test - 19 locations, 2 replications/location.
4. ADD demonstrations.

3.5 Low fertility evaluations
At stage number three, (intermediate phase), two sets of trials will be evaluated at each location. One set at normal fertility levels, and the other set at zero fertilizer in order to identify genotypes that can do fairly well at low fertility levels.
4. LINKAGE WITH THE NATIONAL SEED COMPANY OF MALAWI (NSCM)

The action plan calls for closer linkage between the Malawi Maize Programme and the NSCM, the institution charged with seed production and distribution in Malawi. In this regard, the NSCM have agreed to carry out what is termed "Seed Production Research". This will involve NSCM getting lines of promising experimental hybrids from the breeders after the first season of evaluation of the experimental hybrids from the NMVTs, to produce the hybrid on a small scale. The advantages of this kind of exercise will be:

1. The NSCM will be able to assess the practicability of producing the new hybrid before it is finally released e.g. the nicking of the parental lines under field conditions.

2. The seed produced, which will be more than what the breeders normally produce under bags, will be used in ADD's for setting up demonstration plots so that extension workers and farmers are aware of the new hybrid. Some seed will also be made available to the Maize Team for more extensive testing.

3. By the time the hybrid is released, farmers will have been aware of it, seed will be available on the market and the NSCM will have had enough parental seed stocks to embark on large scale production.

This kind of collaboration will start in the 1989/90 season with a top-cross hybrid of MH12 x Pop32. This hybrid was evaluated during the 1987/88 season by the Maize Breeders at Chitedze and the top-cross hybrid was found to be better than MH12 in both yield and grain texture (had harder endosperm). This kind of hybrid could be used in the interim period while the Maize Programme continues its tests of their newly developed hard endosperm hybrids.
5. COLLABORATION WITH INTERNATIONAL MAIZE INSTITUTIONS

Collaboration with International Maize Institutions such as CIMMYT (both Harare and Mexico), IITA, SARCCUS, etc will be strengthened. This will enable acquisition of exotic germplasm which is of crucial importance at the time when the breeding programme needs to diversify its germplasm resources. The CIMMYT Harare station in particular, will play a major role in supplying germplasm and also for screening for maize streak virus disease because of the good facilities the station has. Maize Scientists from the Malawi Team will make several visits to the station in order for them to select materials which are useful to our programme. At the same time, the CIMMYT Harare Scientists are expected to visit the Malawi Maize Programme in order to monitor the action plan.
6. GERMLASM AND SOURCES

List of initial germplasm to be used in population improvement programme:

<table>
<thead>
<tr>
<th>Ecology</th>
<th>Material</th>
<th>Source</th>
<th>Maturity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mid-Altitude</td>
<td>UCA</td>
<td>Local</td>
<td>Long</td>
</tr>
<tr>
<td></td>
<td>Chitedze 8244</td>
<td>CIMMYT</td>
<td>Long</td>
</tr>
<tr>
<td></td>
<td>Population 43</td>
<td>CIMMYT/IITA</td>
<td>Long</td>
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<td></td>
<td>Population 32</td>
<td>CIMMYT/IITA</td>
<td>Intermediate</td>
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<td>Long</td>
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<tr>
<td>Lakeshore</td>
<td>CCA</td>
<td>Local</td>
<td>Long</td>
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<td></td>
<td>CCC</td>
<td>Local</td>
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<td>Population 49</td>
<td>CIMMYT</td>
<td>Intermediate</td>
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<td></td>
<td>Kalahari Early</td>
<td>Local</td>
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<td>Pearl</td>
<td>Local</td>
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<td>Shire Valley</td>
<td>CCD</td>
<td>Local</td>
<td>Early</td>
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<td></td>
<td>Population 30</td>
<td>CIMMYT</td>
<td>Early</td>
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<td></td>
<td>NSCM41</td>
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<td>Intermediate</td>
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<tr>
<td></td>
<td>MH16</td>
<td>Local</td>
<td>Intermediate</td>
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Note that this list is not a complete one because materials will constantly be fed into the programme from other sources, as they become available.
List of germplasm to be used in the hybrid programme:

Standard Homozygous local and exotic (South Africa) lines = 100 lines
$S_1$ lines from local landraces = 798 lines
$S_2$ lines from local landraces = 219 lines
Inbred lines from CIMMYT (Mexico) = 30 lines
IITA inbreds = 60 lines
Inbred Bulks from CIMMYT (Harare):

HA 88B - 105 = 189 lines
HA 88B - 106 = 100 lines
HA 88B - 107 = 262 lines
HA 88B - 110 = 300 lines
7. MAIZE PATHOLOGY RESEARCH ACTION PLAN

7.1 Introduction

The maize crop in Malawi is exposed to a number of diseases that reduce both yield and quality. In some localized areas disease epidemics have developed with severe consequences for maize growers.

Very limited disease studies have been conducted in the country over the past few years. As a result quantitative information regarding the current extent and impact of diseases on the yield of maize in the country is very scanty.

The maize pathology research programme is designed to assist in the development of superior germplasm adapted to the growing areas and the farmers needs in the country, to support the maize breeding activities in effective disease resistance screening to helminthosporium blights, puccinia rusts, maize streak virus disease (MSVD) and other maize diseases of importance in the country. The programme also focuses directly on the development of integrated maize disease control strategies suitable foe maize growers in the country and, generating information on pathology aspects. To strengthen the activities of the programme, the plan calls for strong co-operation with other institutions from within and outside the country on the research of the basic biology, ecology and epidemiology of the diseases. CIMMYT (Harare) will assist in maize streak virus resistance breeding or conversion of the Malawi maize materials so that they are streak resistant.

Maize pathology research priorities include the establishment of disease nurseries, assigning priorities to disease problems, assisting breeders in developing disease resistant materials through providing inoculum, inoculating and evaluating materials, developing multiple disease
resistant materials and generating integrated maize disease control strategies rather than host resistance.

In the first phase, the plan focuses at disease priority setting in the country, disease epidemic monitoring, host resistance breeding against the most economically important diseases (helminthosporium leaf blights, puccinia rusts, cob rots and MSVD) and virulence studies of the helminthosporium leaf blight pathogens. The plan also focuses on the etiology, epidemiology, distribution, histology and control of other maize diseases.

Since the pathology programme supports the breeding programme, the phase length and number of phases depend very much on the activities of the breeding programme.

7.2 Timetable for maize pathology

In the disease resistance breeding activity, the materials to be handled are those generated in the population improvement program. An S1 progeny breeding system will be adapted and one cycle will take three seasons.

1988/89 Summer
89/1. Disease survey started to prioritise the diseases.
89/2. Collection of inoculum of helminthosporium sp. and cob rot pathogens and inoculum multiplication.
89/3. Final year for evaluation of yield loss due to cob rots and writing up of experimental results.
89/4. Preliminary screening of some materials against MSVD under natural infection.
89/5. MSVD epidemiology studies initiated.

1989/90 Summer
90/1. Disease survey continued and completed.
90/2. Construction of S1 families from the Malawi local collections and exposing them to helminthosporium
sp., cob rots, and selecting the best 3000 plants and then 1000 ears from the best plants at harvest.

90/3. Screening of the Malawi local collections, CCD lines against MSVD under artificial pressure by CIMMYT in Harare.

90/4. Collaborative work with CIMMYT, Harare.

1990/91 Summer

91/1. Conversion of promising experimental lines to maize streak virus resistant lines.

91/2. Evaluation of S1's constructed in 90/2 and development into S2 under disease pressure.

91/3. Set up Helminthosporium sp. virulence and yield loss assessment studies.

91/4. Construction of S1 families of the population improvement breeding nursery under Helminthosporium sp. pressure.

91/5. Maize streak virus epidemiology and yield loss assessment studies.

91/5. MSVD strain differentiation studies.

1991/92 Summer

92/1. Construction of S1 families from the streak converted materials.

92/2. Yield test of S2 materials developed in 91/2 in sets of 20 at two locations. Select the best 40 with or without disease pressure.

92/3. Evaluation of S1's constructed from the population improvement breeding nursery and development into S2 under disease pressure.


92/5. MSVD resistance reaction pattern studies initiated—Collaborative work with CIMMYT, Harare.

92/6. Disease inoculum increase.
1992/93 Summer.

93/1. Evaluation of the MSV Resistant converted materials under artificial disease pressure and advancing them further at CIMMYT, Harare.

93/2. Hand over the best families to breeders for making experimental varieties. END OF CYCLE ONE.

93/3. Yield test of S1's selected in 92/3 in sets of 20 at two locations. Select the best 40 with or without disease pressure.

93/4. Helminthosporium sp. virulence and yield loss assessment studies continued.

93/5. Disease inoculum increase.

1993/94 Summer.

94/1. Hand over the best families of 93/3 to breeders for making experimental varieties.

94/2. Begin cycle two of some elite materials of 92/2 and 93/3.

94/3. Start new cycle with fresh materials as they come in the pipeline from the population improvement programme.
8. AGRONOMY

8.1 Introduction

The agronomy research plan more directly addresses the needs of the full range of farmers that grow maize in Malawi. Some research thrusts are targeted towards the estate sector and smallholder farmers growing dent hybrids mainly for sale; others examine practices for the new flint hybrids expected to be grown at medium input levels by smallholder farmers for retention and sale and by the estate sector. Yet others focus on the development of agronomic practices for flint hybrids and other improved materials when grown by smallholder farmers using few external inputs.

The focus is on a more production problem orientated, solution seeking, multidisciplinary approach than that adopted in the past. The general problems to be addressed have been widely appreciated as the most important technical agronomic problems facing maize production in Malawi. But, in some cases, the details of the problem or its causes are not known or in doubt. The severity of a problem, its important causes or relevant solutions may differ with agro-ecological zone, farmer group, changes in input/output pricing policy etc. Accordingly, a strong diagnostic element and necessary investigative studies are incorporated into the early years of the agronomy part of the Maize Action Plan. The backbone of the work will remain the agronomic on-station or on-farm field experiment, particularly for the development and testing of technologies, but other techniques will also be used.

Agronomic and socio-economic activities exclusively related to the new flint hybrids are described first and then other activities are given by research thrust.

8.2 Agronomic and socio-economic activities for the flint hybrids

In this section we describe research that will take place on the development and verification of agronomic input levels
and practices to allow the efficient, economic production of flint hybrids by smallholder farmers in Malawi.

8.2.1 Survey

A survey of farmers related to their current use of hybrid, composite and local maize and monitoring of the practices farmers result in employing with the new flint hybrids (see section 9.2). The survey will start during the 1989/90 maize production season. The timing of the second part will depend on when some farmers adopt the flint hybrids.

8.2.2 Fertilizer responses

Fertilizer responses of the new flint hybrids vs current dent hybrids, composites and locals will be assessed on-farm, in the 1989/90 to 1993/94 maize seasons at several levels of inorganic fertilizer under monoculture and intercropping appropriate to the agro-ecological zone.

The trial will be started 1989/90 season with two semi-flint hybrids (MH12 x Pop 32 for high potential zones, MH16 x Pop 32 for lower elevation areas). In further years more 'flint' hybrids (and other flint materials) from the breeding programme are expected to be included in the trial. The trial will be conducted at approximately 20 research trial sites/stations and 30 smallholder farmers fields throughout the country covering the major soil types and agro-ecologies. These on-farm trials will be run jointly with ARTs and will be largely farmer managed at farmer levels of inputs. These on-farm trials will be the main agronomic test of the performance of new flint materials under farmer conditions and will include farmer assessments of the varieties and economic analysis. A set of provisional recommendations will be released to farmers after the trials have run for three seasons through the Technical Clearing House of the Ministry of Agriculture.

8.2.3 Intercropping

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The intercropping performance of flint hybrids will be assessed. Starting in the 1989/90 season MH12 x Pop32 and MH16 x Pop32 will be intercropped with appropriate legumes and other crops in on-station trials. Proportions of the crops, and the timing of planting of the companion crop in relation to maize will be examined. New flint hybrids will be examined in these trials when available.

8.2.4 Assessment of Grain Storage Losses
Grain storage losses of flint hybrids will be assessed and compared with dent hybrids and local maize stored using traditional methods on-farm, with and without protection by pesticides. This will be done starting the end of 1989/90 season jointly with breeders and the Crop Storage Unit.

8.2.5 Plant Population Density
Plant population studies on-station will examine between row and within row plant spacings to compare flints with current dents x agro-ecological zone. These trials will begin in 1990/91 maize season for three seasons.

8.2.6 Weed Control
Verify timing of mechanical weed control for the flints and determine under which circumstances chemical weed control is viable, starting 1990/91 for three seasons.

8.2.7 Physiology of Dry Matter and Mineral Nutrient Partitioning
This will be determined for the new flints and compared with dents. A start will be made in 1989/90 in comparing MH12 x Pop32 with MH12 and MH16 x Pop32 with MH16, and other materials will be evaluated as available.

8.2.8 Climatology Studies
Examine the Fit into the Rainfall Season and Drought Tolerance of new flint materials developed for the lower Shire and Lakeshore areas on-station, and on-farm under farmer
planting dates and management, starting 1991/92 for approximately 4 years.

8.3 General agronomic research thrusts

These thrusts address several important general and complex agronomic problems related to the production of maize in Malawi to which solutions are urgently required but are difficult and elusive. Research on these aspects does not specifically depend on the development of flint hybrids or any other particular type of maize germplasm; instead it focuses initially on gaining a more complete understanding of the problem areas and their causes with a view to developing solutions in the longer term (in 5-10 years time).

8.3.1 Soil fertility and nutrient cycling

8.3.1.1 Fertilizer Use Efficiency

A start has been made on examining fertilizer use efficiency in three respects:

1. The timing, amount and placement of higher analysis basal and top dress fertilizers have been examined in on-station and on-farm trials since the 1986/87 season, to develop efficient practices for the use of high analysis fertilizers on current hybrids. This work is a response to the government policy shift towards importing just higher analysis fertilizer (i.e. urea and DAP). These trials will now be written up and the results and interpretation circulated to extension staff by October 1989. A modified set of trials will start 1989/90 involving composites in addition to hybrids.

2. 'Local' maize has been evaluated in on-station and on-farm trials since 1987/88 for its responsiveness to N fertilizer under monoculture and intercropping. This set of trials will continue until 1989/90 and will be written up with conclusions by October 1990.

3. Another trial, started 1987/88, has looked at the response of hybrids and local maize to lower levels of P fertilizer and will continue until 1989/90.
Output from these trials on fertilizer use will help define appropriate fertilizer use recommendations for the different agro-ecological zones and categories of farmers in the country. This will be a continuous refinement exercise. An overall written synthesis of the results of work on fertilizer use efficiency will be developed by the end of 1991.

A new research thrust will be initiated to look at the response of maize to trace elements identified as limiting by the Maize Commodity Team and the Soils Team e.g. S, Zn, Bo and at Al$^{3+}$ toxicity on acid soils in the Dedza Hills and the Viphya Plateau. This work will be done together with the Soils Team and should start 1990/91 - 1995/96.

8.3.1.2 Sustainable Systems with High Internal Cycling of Nutrients.

Some aspects of this thrust have been ongoing for several years. e.g. intercropping studies by the maize team, (and the agro-forestry work by the Soils Team), but the aim now is to draw together various existing and new research themes around the common objective of developing sustainable soil fertility management system, with less dependence on high cost inorganic fertilizers. These systems should be mainly for the smallholder farmer who has few resources, has difficulties in gaining credit, and is using very little or no fertilizer at present. Findings will also be important in seeking ways of reducing the dependence on inorganic fertiliser of estates and smallholder currently using high input management.

Soil fertility on most smallholder farms is low while use of expensive inorganic fertilizers is extremely low and may go lower if, as expected fertilizer subsidies are removed. It is reported that in the 1986/87 season only 23% of smallholder farmers with land holdings less than 2.5 ha used fertilizers on maize.
Research is needed to develop and test systems of maize production that maximize the within-system cycling of nutrients and minimize the need for inorganic fertilizer inputs. Several highly complementary research thrusts will be developed to address this, including:

a) Intercropping  
b) Agro-forestry  
c) Organic fertilizer sources, and  
d) Nitrogen fixation in legumes

It is proposed that this work take place in two phases: Phase 1, using surveys, monitoring and analyses to look at the current soil fertility problems on farmers' fields; and Phase 2 to develop and run detailed studies on soil/plant nutrient cycling processes and longer term soil fertility management trials to address issues that arise from Phase 1. This programme will be jointly developed and undertaken by the Soils Team and the Maize Team.

Phase 1 : 1989/90

Phase 1 will evaluate the potential of various cropping systems and associated farming practices for soil conservation and fertility stabilization. Use will be made of:

a) existing information based on current and past trials in Malawi,  
b) diagnostic survey and monitoring of current small-scale farm status and practice concerning soil fertility in the 1989/90 season, starting in October.

The first activity will be a review of current information from Malawi and neighbouring countries on soil fertility and farming practices. The ARTs have a lot of valuable information on this that requires synthesising. This will be completed as a short term consultancy by November, 1989. If further information is then required appropriate
means will be employed to get the information. This will take the form of a diagnostic monitoring survey to evaluate soil characteristics, farmers perceptions of soil fertility and problems, fertilizer patterns, uses of crop residues etc.

**Phase 2: Starting 1990/91**

Experimental studies of a number of key aspects of nutrient cycling under varying agro-ecological conditions are required. The Malawi Maize Agronomy Planning meeting that took place January 1989 suggested several detailed studies on nutrient cycling processes, specifically:

- Efficiency of production and N fixation in legumes of choice.
- Mineralization capacities of soil in relation to climatic change and crop physiology.
- Decomposition and nutrient release rates and patterns for crop residues and organic inputs.
- Patterns of soil nutrient movement and loss in relation to soil moisture change.
- Beneficial and deleterious behaviour of soil fauna in relation to organic inputs.

Some of these studies will build on current work by the Soils and Maize Teams (e.g. the first and the fourth studies immediately above), and will start in September 1990. A soil scientist post-doc, funded by the Rockefeller Foundation and jointly in the Maize and Soils Teams, and postgraduate research students will carry out this work.

The second and most important part of Phase 2 involves trials of management options for improved soil fertility. The content and structure of these trials will be based on results of Phase 1 and so cannot be specified at this time, but will probably include variations in crop residue use, in tillage
and in fertilizer application within intercrop, relay crop or agro-forestry systems.

Some of these trials will be long-term monitoring trials looking at changes in the soil organic matter fraction, mineral nutrient status, and physical land mineralization characteristics.

**8.3.2 Drought tolerance and stand establishment: 1989-1995**

Poor rainfall distribution and drought are frequent in low lying areas of Malawi, such as the Lakeshore and the Shire Valley and in some higher elevation rain-shadow areas such as Nkhamanga Valley, Kasungu, the Chitipa plain, Chileka, Phalombe plain and Mwanza. Some indicators suggest these constraints have become more severe in recent years.

There is little empirical evidence at the moment on the main production problems associated with water deficits in Malawi but indications are that problems associated with shortage of moisture included poor germination, poor emergence and stand establishment, late planting, inefficient use of fertilizer and labour, and drought symptoms, on plants during the growing season. A methodical programme of observations on the extent and effects of water deficits will be needed to guide the agronomy research and to guide breeding.

A compilation and analysis of daily rainfall data over at least 10-20 years, from several meteorological stations in the dry parts of the country, in relation to development of the maize crop, will be done as a top priority for completion by December 1989. A student from Bunda College has been engaged starting July 1989 to do this. Output from this study should better orientate agronomy and breeding work for the dry areas. The risk associated with fertilizer use in areas of unpredictable rainfall requires careful agronomic and economic analysis.
Trials started in the 1988/89 season, looking at plant population densities for short plant stature composites (CCC, CCD) in the dry areas, will continue.

It would appear that poor stand establishment is a major problem in smallholder maize production especially in dry areas, leading to higher cash and labour costs. This is in part a result of the low vigour of existing 'local' maize seed. However, other causes that have been identified include soil crusting, uneven depth of planting and planting part of the crop into drying seedbeds. Late planting (and gap filling in earlier planted fields) leads to reduced yield expectancy. There is a need to quantify these and other causes and to better understand farmer practices in relation to land preparation and planting under limited moisture. A detailed survey looking at the stand establishment from improved seed and local maize is planned to occur in the dry areas at planting time during the 1990/91 season.

The agronomic trials for dry areas (planned to start in 1991/92) will focus on economic ways of bringing forward actual planting dates, reducing the risk of poor emergence/stand establishment on drying seedbeds (including developing guidelines for planting on drying seedbeds) e.g. by more stable planting methods, concentration of water during the growing season by appropriate methods (e.g. flat vs. ridge planting, tied ridges). Studies on the relationship between seed size and establishment vigour/ability to break through crusts, are also worthwhile.

Agronomy may be required to assist breeders with selection criteria or in the development of appropriate selection and testing environments for their drought work. The synchrony of pollen shed and silking under drought is regarded as a useful trait for maize to have. Plasticity of
ear production (the ability to put on more than one ear per plant at low plant population densities) should also be investigated. New varieties may be screened for their ability to emerge from drying seedbeds. All of these efforts may require input from physiology/agronomy.

8.3.3 Weed research: 1989-1994

It has been well documented that weed competition and associated yield losses are a major constraint for both the estate sector and smallholder. Many studies, including several by ARTs, have shown that the first weeding by smallholder is done late, resulting in considerable yield losses, because of other conflicting activities and that a second weeding may not occur. Ways of improving the efficiency of herbicide and mechanical weed control are still required for the estate sector. Smallholder require an array of weed management possibilities to choose from to reduce the major losses they suffer in both hybrids and local maize.

The maize team plans to conduct work in the following areas:
For the estate sector and larger smallholder the long established trial programme to screen the effectiveness and economic viability of new herbicides for monocrop and intercrop maize will continue as necessary.

For smallholder, likely practices to be investigated for their ability to suppress weeds include intercrops and plant densities and spatial arrangements. Specific characters of maize that may confer the ability to compete with weeds e.g. seedling vigour, need incorporating into the evaluation of new maize varieties. Ways of reducing the time needed to hand weed monocrop and intercrop maize merit attention, as does the possible introduction animal drawn cultivators (in cooperation with the Farm Machinery Unit). A watch on Striga buildup will
be made in conjunction with an extension efforts to train farmers to remove individual Striga plants before seed set.

8.3.4 Intercropping and relay-cropping studies
These studies will continue but with more emphasis on targeting trials to appropriate groups of farmers or areas where that intercrop is or might be grown. More emphasis will be placed on the soil nutritional aspects of intercrops as described in 7.1.2.

8.3.5 Plant population density studies
These will continue to be required on a routine basis as new maize varieties (mainly flint hybrids) are released by the breeders. Plant population density studies (in relation to agro-ecological zone and expected fertilizer use level) will be done on the new flint materials starting the season after their release.

8.3.6 Crop physiology: 1990-1995
There is an important role for crop physiological studies, especially on the issues that are the boundary of breeding and agronomy e.g.:

1. helping develop appropriate and effective selection criteria and selection environments for drought resistance, stand establishment and weed tolerance work.

2. helping assess the progress from breeding more fertilizer use efficient maize varieties (e.g. dry matter production /unit of N fertilizer), and progress with the aims mentioned under 'a').

8.3.7 On-farm seed selection and storage
Little is know about how farmers save local and composite seed from their fields for planting in the next season. Even given the most optimistic assumptions about the rate of adoption of new flint hybrids, many farmers will continue to plant local and composite varieties for years to come.
Understanding farmers' seed selection and storage practices will help to indicate the strategies that farmers themselves use for germplasm maintenance. What little is known suggests it is rare for seed to be selected from the field and given special attention, rather the seed is taken from the crib or bin at random, just before planting.

A detailed survey of farmer practices on selection, storage and preparation of seed for planting will be undertaken as a student project, at the end of the 1989/90 season.
9 ON-FARM RESEARCH, SOCIO-ECONOMIC COMPONENT AND EXTENSION ACTIVITIES

9.1 Linkage with adaptive research

Many of the agronomy activities described in 6 and 7 have a strong on-farm research component, involving problem oriented surveys and monitoring activities and on-farm trials. The Adaptive Research Coordination Unit and individual ARTs are already involved closely with the Maize Commodity Team on agronomic research for maize. Joint research programme planning will continue to occur, with an expected increase in joint activities. Emphasis will be on developing agreed common objectives and implementation so that both teams give the work high priority.

9.2 Surveys, monitoring and socio-economic analysis

Several survey activities have already been discussed in conjunction with the agronomy action plan. Surveys of farmer crop management practices, particularly as they relate to different kinds of germplasm, are especially important. Surveys and analysis should proceed in several phases. Many bits of evidence concerning farmer practice in the key areas of varietal choice and fertilizer use already exist. It is important to consolidate, synthesize, and analyze these results. This will be undertaken by the CIMMYT economist based in Malawi beginning in 1989.

Nonetheless, there are still many gaps in what is known about farmer practices and the reasons for these practices. These gaps should be filled by research conducted both by Adaptive Research Teams and by special student projects, beginning in the 1989/90 maize cycle. Information from this research should also be supplemented with continuous monitoring of the uptake of new materials flowing from the maize research team, as well as the practices farmers employ in conjunction with these materials. This monitoring should be the responsibility of ADD Evaluation Units, although Adaptive Research Teams might also be involved. In general
division of labour between Adaptive Research Teams and Evaluation Units should be determined more by the practicalities of available personnel than by preconceived notions of responsibilities.

A related important part of the socio-economic work will be to provide the breeding and agronomy programmes with information on current and projected farmer circumstances for different target groups of farmers. The Maize Team will wish to target the different types of farmer in Malawi more explicitly with their research. A significant amount of diagnostic work categorising farmers has been done by Adaptive Research Teams, Malawian social scientists and outside researchers. This diagnosis has divided farmers by the types and levels of resource constraints they face. Further refinements might follow from the realisation that categorisation of farmers might change depending on the innovation considered (e.g. new hybrids or fertiliser use). This refinement will receive attention from the CIMMYT/USAID economist during 1989/90. That work may suggest possible useful refinements to farmer groups, to which breeders and agronomists will address their work.

A further related economics activity will also generate information regarding the storage and consumption properties of new materials developed by the maize team. Survey work on the desired characteristics of improved maizes is required urgently and will be started towards the end of 1989. To obtain the necessary wide coverage this work will be supervised by either Evaluation Units or Adaptive Research Teams in cooperation with the Extension Service. Such cooperation will increase the awareness by extension of the different types of maize available in Malawi and their advantages, and will also help extension systematically assess areas planted to different types of maize. Coordination with the Crop Storage Unit and the studies of poundability/palatability conducted by the Maize Team itself
are also highly desirable. In the initial stages, this evaluation should focus on sites where the Maize Team is testing new materials under farmer conditions.

An important routine activity of the economics programme will be to analyze results on agronomic and germplasm technologies being worked on in the Maize Team in order to judge their likely economic and social worth to the farmer. This is already being done by adaptive research teams, and should be continued. A further component consisting of farmer assessment of trials should be added to the economic analysis. Since the current high cost of fertilizer is a major constraint on maize production by all sectors, some of the more important analysis that will be undertaken concerns the economic use of high analysis N fertilizers which have been introduced to reduce the cost of importing N into Malawi.

A longer term effort will be to improve the current state of knowledge concerning the areas planted to improved maize materials. Current estimates, usually provided by extension, are based on seed sales which ignore areas planted to retained seed of composites/open pollinated varieties. In the long run, better estimates will have to result from three factors: 1) better methods of identifying improved materials several generations after the seed has left the distribution system; 2) better knowledge by the extension service of the germplasm actually available; and 3) streamlining of the national sample surveys of agriculture.

The economic component will also provide a close link between maize research and national agricultural policy. Pricing of inputs and outputs, and restructuring of institutions serving smallholder agriculture, will obviously have effects on the adoption of improved technology. Better channels of communication between the various individuals and institutions conducting the studies mentioned above and the planners and policy makers should be developed.