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THE IMPACT OF MAIZE RESEARCH IN MALAWI

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ABSTRACT

This paper presents a chronology of maize research in Malawi, a summary of aggregate adoption data for improved cultivars, and estimated rates of economic return to maize research. By international standards, the time-to-release of hybrids that are adapted to small farmer condition is moderate. Adoption rates for maize hybrids began to rise rapidly even before the release in 1990 of semi-flint hybrids. Estimated rates of economic return to maize research are high.

INTRODUCTION

Maize research in Malawi has been characterised as a failure by some observers, based on aggregate adoption data and the record of varietal releases through the mid-1980s (Kydd, 1989). This paper uses a chronology of maize research, more recent adoption data, and conventional economic methods to calculate the economic rate of return to maize research in Malawi. Results suggest that Malawi's maize programme is better characterised as a success than a failure.

Malawi's breeding programme is unique in that, in addition to yield criteria, the issue of whether to breed cultivars with flint or dent grain texture has motivated research strategies since the colonial period. On the farm, flint varieties can be processed more efficiently into the fine white flour (*ufa woyera*) Malawians prefer to use in preparing their staple food (*nsima*). Flint cultivars are also more resistant to insect infestation under on-farm storage conditions than dent cultivars. However, most of the higher-yielding, improved germplasm that was bred in the region and globally has been dent. The focal maize breeding question in recent years has been how to generate the high yields demanded by Malawi's commercial growers while meeting the consumption needs of Malawi's small farmers.

Between the release of the semi-flint hybrid, LH11, by the colonial programme and the development of the semi-flint hybrids, MH17 and MH18, by the national programme, the programme produced both flint open pollinated varieties (OPVs) and dent hybrids. Swings in research emphasis between breeding flint OPVs for small farmers and dent hybrids for commercial farmers, lack of suitable flint germplasm for developing flint inbred lines[1], as well as staffing and funding discontinuities affected the progress of research[2].

In addition to the grain texture issue, a nexus of socioeconomic and institutional factors outside the purview of the breeding programme have contributed to the shape of the adoption curve for maize hybrids over the years. Seed production problems, relative prices for cash crops, high nutrient to grain price ratios, and the method for diffusing seed and fertiliser contributed to stagnating adoption rates for dent hybrids through the mid-1980s.

Aggregate adoption rates for maize hybrids began to climb even before the release in 1990 of two semi-flint hybrids bred by the national programme. The relatively short amount of time invested in the hybrid programme, the modest investment in maize research, and the steep slope of the cumulative adoption path

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1 Inbred lines developed from local flint materials are too tall and their growing season is too long (Zambezi, personal communication). Exotic flint germplasm is difficult to locate because most breeding efforts for maize hybrids in other parts of the world have emphasised dents. Technology development in southern and eastern Africa has been restricted by the belief that dent maizes have a higher yield potential than flints (Blackie, 1989).

2 For details on funding and staffing, see Kydd (1989).

generate high rates of economic return to maize research. Evidence further suggests that the semi-flint hybrids satisfy both the yield and grain texture criterion. MH17 and MH18 appear to be suitable for both large farmers who produce for sale and small farmers who produce for home consumption[3]. In other words, as long as other socioeconomic factors remain favourable for adoption, research benefits will also be distributed more widely within the farm population.

A critical determinant of the rate of economic return to research is the time period of research. In order to identify the appropriate time period for analysis, the next section presents a timeline of maize breeding in Malawi. The second section presents two types of adoption data: 1) the aggregate adoption data used to calculate economic returns, and 2) data on hybrid maize adoption by percentage of farmers and farm size, which are used as a basis for statements about the distribution of research benefits. The third section outlines some of the non-breeding factors affecting the changes in adoption data over time. The final section presents the method and results for the rate of return analysis.

A CHRONOLOGY OF MAIZE RESEARCH

In 1954, as part of the first plant breeding programme, R.T. Ellis began maize research into synthetics (OPVs with a relatively narrow genetic base) and hybrids. The most promising of the new cultivars were the semi-flint synthetics SV17 and SV37 and the semi-flint hybrid LH11. Pre-independence pressures within the colonial administration led to Ellis' resignation in 1959. No breeder replaced him for three years, although he visited the research station periodically and attempted to maintain breeding lines with the assistance of national technicians (Ellis, 1992).

After independence, the post of plant breeder was filled intermittently by a series of expatriates on short-term contracts (GOM/DOA). Plant breeders had responsibility for both maize and tobacco, and except for some early work on composites by P. Kyle and H.G.S. Selley, during the late 1960s, research efforts focused on the testing of existing lines rather than the release of new materials. Through much of the period from 1959 to 1967, breeding lines deteriorated because of vacancies, shortages of supplies and limited funds (Zambezi, 1992). In 1967 the hybrid programme was officially "discontinued" (Mloza-Banda et al., 1988).

In 1971, a British Overseas Development Team led by A. Bolton was posted to the Malawi research system. Bolton's research time was devoted exclusively to maize. In a series of trials comparing the performance of the hybrids and synthetics bred before independence to imported composite and hybrid materials, Bolton concluded that the dent hybrid SR52 (of Rhodesian origin), and the semi-flint composite UCA (of Tanzanian origin) were most promising. Bolton described SR52, the highest-yielding cultivar, as appropriate for the small sector of Malawian commercial farmers who could produce it for sale under high-management conditions[4]. National breeding efforts could then be concentrated on the development and adaptation of semi-flint composites for consumption or sale by small farmers (Bolton, 1974). Through the late 1970s, compared to the earlier period, the programme adopted a two-pronged strategy of importing a high-yielding dent hybrid for commercial farmers and testing flint composites for small

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3 Both trial and demonstration results show that the yield differences among the various Malawi hybrids are on the average minor (GOM/DAR). For evidence on yields under low-input conditions, see Jones and Heisey, 1993. For evidence from farmers about processing and storage, see Smale et al. (1993).

4 The yield of a single-cross hybrid like SR52 is generally higher than that of a double-cross like LH11. In the 1960s, the yield of LH11 at the national research station was approximately 8 mt/ha. In both station and district trials during the early 1970s, yields of Zimbabwean double-cross hybrid ranged from 90 to 125 percent that of LH11. Considering both the yield losses from line deterioration in the 1960s, and those associated with on-farm processing, LH11 should have been quite competitive with the double-crosses. On the other hand, the single-cross hybrid SR52 consistently yielded 30 to 55 percent more than LH11 (Bolton; GOM/DOA).

farmers. CCA and CCB were developed by the composites programme.

In 1977, after a ten-year hiatus, the hybrid programme was officially restored (Mloza-Banda et al., 1988). One of the motivating forces behind this decision was the high cost of importing SR52 from Zimbabwe after United Nations (UN) sanctions were imposed on Ian Smith's regime. Pressure to replace costly seed imports led to the release in Malawi of the dent hybrid MH12. Based on Zambian (renamed MM752) germplasm, MH12 yields less under comparable conditions than Zimbabwean SR52 because the breeding lines were contaminated (Zambezi, 1992).

Releasing MH12 was an "import-replacement" strategy. The two-pronged breeding strategy continued through the 1980s. From 1978 to 1981, the national breeders and technicians developed the lines for the adapted, dent hybrids, MH14-16, and the semi-flint composites, CCC and CCD. When all of the national breeders left for advanced training in 1981, the technicians maintained the newly developed hybrid and composite lines. In the mid-1980s, the National Seed Company of Malawi obtained foreign exchange clearance to import the F1 for NSCM41 (Ciba-Geigy 4141, related to Zimbabwe hybrid R201), a dent, short-season hybrid. MH14-16, CCC and CCD were officially released by the national programme.

Shortly thereafter, high rates of rejection of dent hybrids by smallholder farmers forced breeders to produce flint hybrids. For the first time, yield and grain texture objectives were combined in both the hybrid programme and the OPV programme. In 1990, B.T. Zambezi, E.M. Sibale and W.G. Nhlane released the national maize programme's first adapted, semi-flint hybrids, MH17 and MH18.

When the active years of hybrid maize breeding are considered, only 17-18 years have transpired since the inception of the hybrid programme to the release of semi-flint hybrids by the national programme[5]. A research lag of 18 years is not long by international standards (see Davis et al., 1987; Pardey and Craig, 1989; Chavas and Cox, 1992), especially when the nature of the research and the level of resources allocated to the research are considered. The research lag is even shorter when measured in terms of person-years rather than calendar years, and the actual number of person-years devoted to the hybrid programme in Malawi is lower than indicated by staffing levels (GOM/DOA, 1975-78; GOM/DAR, 1979-1992).

ADOPTION OF IMPROVED CULTIVARS

Percentage of Farmers

Figures from the National Sample Survey of Agriculture (NSSA, 1980-81) show that the percentage of farmers growing maize hybrids and first-year composite seed in Malawi was roughly equivalent at 5 percent in 1980/81[6]. Except for the 1990/91 season, the adoption rate for composites appears to have declined since then. After a slight downward movement in the mid-1980s, the percentage of farmers growing hybrid maize had risen dramatically (Table 1).

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5 When the decision was made to breed flint hybrids, the scientific process required only three years. The team used an unconventional top-cross method. For each semi-flint hybrid, one parent from Malawi's dent hybrids was bred with a parent from Population 32, a flint material requested by the team and obtained without royalties from scientists at CIMMYT. The innovation was the result of years of drudgery of line development and maintenance by technicians, the serendipity of the idea to use a top-cross technique, and scientific collaboration.

6 NSSA and Annual Survey of Agriculture data sources provide adoption information only from 1980.

Table 1: Percentage of Smallholders Growing Composite and Hybrid Maize.

Year	Agricultural Development Division			
	Blantyre	Lilongwe	Kasungu	Mzuzu
Composites				
1980/81	2	3	10	14
1985/86	2	1	1	3
1986/87	1	1	0	1
1987/88	2	0		2
1988/89	0	0	0	3
1989/90	1	2	1	2
1990/91	7	11	1	9
Hybrids				
1980/81	1	15	8	12
1985/86	1	12	27	24
1986/87	1	5	26	15
1987/88	4	9		20
1988/89	8	7	26	18
1989/90	14	22	33	38
1990/91	30	34	39	40

Source: National Sample Survey of Agriculture, 1980-81; Annual Survey of Agriculture 1985-1989; CIMMYT/MOA Maize Technology and Varietal Adoption Survey, 1989-91; Food Security and Ministry of Agriculture, 1990 and 1991.

Percentage of Maize Area and Production

Expansion of aggregate area planted to hybrids has grown at equivalent rates but has reached lower cumulative percentages (Table 2) because when farmers adopt dent hybrids, they continue to grow local maize for their subsistence requirements (Smale et al., 1991). Since semi-flint hybrids are similar to local maize in terms of processing and storage characteristics, the two adoption indicators (percentage of maize area; percentage of maize farmers) may converge over time as farmers learn that some hybrids are suitable for sales as well as for home consumption.

Table 2: Hybrid Maize as Percentage of Maize Area and Output

Year	Agricultural Development Division					Malawi
	Blantyre	Liwonde	Lilongwe	Kasungu	Mzuzu	
<u>Percentage of Area</u>						
	-	1	10	5	6	4
1980/81	1	1	9	13	14	6
1984/85	1	-	6	14	14	6
1985/86	1	1	3	8	8	3
1986/87	1	2	4	11	13	5
1987/88	3	3	6	12	14	7
1988/89	4	5	11	14	22	10
1989/90	10	10	14	15	18	13
1990/91	10	11	20	19	19	16
1991/92	28	15	19	39	31	24
1992/93						
<u>Percentage of Output</u>						
	-	1	25	10	14	11
1980/81	2	2	20	27	39	17
1984/85	1	1	15	27	44	16
1985/86	2	2	6	16	28	8
1986/87	3	4	9	20	30	11
1987/88	7	9	13	22	40	16
1988/89	12	16	26	27	55	26
1989/90	25	28	35	35	47	33
1990/91	23	39	47	40	53	43
1991/92	52	41	43	62	61	50
1992/93						

Source: National Sample Survey of Agriculture, 1980-81, National Statistical Office, Government of Malawi; National Crop Estimates, Ministry of Agriculture, Government of Malawi, 1984-1993.

Most recent data indicate that the percentage of national maize area planted to all (dent and semi-flint) hybrids in 1992/93 was from 20-24 percent and higher in the major maize-producing zones (Table 2)[7]. Hybrids are expected to generate half of total maize output in the 1992/93 season (National Crop Estimates).

Adoption by Farm Size

The relatively high percentage of farmers planting hybrids in the last few seasons also implies that the diffusion of hybrid maize has spread to farmers in smaller holding size categories. In general, farm areas in the Blantyre Agricultural Development Division are more heavily concentrated among the lower size classes than those in Lilongwe, Kasungu, and Mzuzu Agricultural Development Divisions. The increase in the percentage of farmers growing hybrid maize in that zone is more rapid than in any of the other zones. Table 3 shows adoption percentages across farm size categories in 19898/90, for Blantyre, Kasungu ad Mzuzu Agricultural Development Divisions. Adoption percentages clearly rise as farm size class increases in the Kasungu and Mzuzu zones, but are not significantly affected by size class in the Blantyre survey zone. For the full sample, an estimated 9 percent of farmers with less than 0.7 ha (some of the smallest in Malawi) grew some dent hybrid maize in the

7 In 1992/93, fifteen percent of the maize hybrids grown by smallholders were donated as drought relief. Roughly 21 percent of total maize area was planted with hybrid seed purchased by smallholders with credit or cash.

1989/90 growing season. Even before the release of semi-flint hybrids, dent hybrids could no longer be simplistically classified as an estate farmers' crop. Smaller farmers and larger farmers may both find it optimal to grow some dent hybrid maize, but for different reasons and with different

Table 3 Percentage of smallholders growing hybrid maize, by farm size.

Farm size (ha)	Agricultural Development Division			All (wtd)
	Blantyre	Kasungu	Mzuzu	
<0.7	14	12	4	9
0.7-1.5	14	28	47	31
>1.5	9	56	56	38

Source: CIMMYT/MOA Maize Technology and Varietal Adoption Survey, 1989-91.

management conditions (Smale et al., 1991; see also Peters et al, 1992)[8].

NON-BREEDING FACTORS AFFECTING MAIZE RESEARCH IMPACT

Adoption rates for dent hybrids rose rapidly from the late 1980s - before the introduction of semi-flint hybrids. Institutional factors other than grain texture clearly influence farmer adoption. Key among those have been the organisation of seed production and distribution and the design of extension programmes.

To be successful, commercial seed production and marketing systems usually require a commercial crop. Most of Malawi's farmers were and are subsistence producers. From the beginning of the maize breeding programme until the organisation of the National Seed Company of Malawi (NSCM) in 1978, seed multiplication and distribution were the responsibility of the Ministry of Agriculture and the Agricultural Development and Marketing Corporation (ADMARC). Although moderately successful in distributing improved OPVs, the Government relied on imports to meet the demand for hybrids. The entry of NSCM and later, Lever Brothers, as profit-making seed enterprises increased the incentives for hybrid seed production and marketing.

With limited private markets for inputs, the dominant diffusion method for inputs has been official credit clubs. Official credit clubs are organised and assisted by extension agents employed by the Ministry of Agriculture. Until recently, farmers were instructed to grow hybrid maize only in pure stands with recommended fertiliser levels. The packages distributed to club members were of fixed size and composition. Club members generally used the input amounts and types allocated to them, on one-acre plots. Package diffusion, although easy to extend and administer, restricted farmers' adaptation of the technology to their own conditions. Further, in the early 1980s, only 10-15 percent of farm households used credit. Extension messages that were oriented to surplus producing smallholders, the difficulty of qualifying for credit, and the risk of default curbed the effective demand for hybrid seed.

A decade later, the percentage of credit-users has grown to 30 percent and higher in the major maize-producing zones. Club members often extend the credit package by purchasing additional hybrid seed and fertiliser with cash. Farmers in more populated peri-urban areas grow small plots of hybrid seed, with or without fertiliser, using cash earned from off-farm income (Smale et al., 1991). The extension programme provides packages of varying size and composition, and is considering recommendation that cash-constrained farmers purchase semi-flint hybrid seed and small amounts of fertiliser, rather than

8 Data presented here are for smallholders only. Only an estimated 8-1 percent of maize output in Malawi is produced by commercial estate In recent years, the growing differentiation among estates rais interesting questions about the role of commercial farmers in hybr maize diffusion (see Mkandawire et al., 1990).

fertiliser for their local maize. Intercropping of hybrids is no longer discouraged.

According to economic theory, input/output price ratios and the relative prices of competing crops should also influence incentives for the adoption of hybrid maize. In practice, the price relationships may be indeterminate. One reason is that the aggregate adoption figures in periods of rapid technological change may represent observations of economic disequilibria, where farmers have not completed their adjustment to new economic and technical conditions (Griliches, 1957)[9] (Knudson, 1991). A second reason, specific to Malawi, is that most farm households both consume and sell maize, and local maize, when sold at all, has usually moved through unofficial channels. The price influencing smallholder decisions is very often not the official producer price. In Malawi, prices are not likely to have been as important as better seed supply and the introduction of semi-flint hybrids in influencing recent hybrid adoption.

Movements in relevant price ratios are summarised in Table 4[10]. Both visual inspection and simple regression analysis of trends, when applied to the data in Table 4, suggest that: (1) over the past 20 years, the price of nitrogen relative to the price of maize has <u>fallen</u> slightly; (2) after initial high prices in the early years of the seed company, relative hybrid seed prices fell in the mid-1980s and then rose again; and (3) the groundnut-maize ratio has had no determinate trend but has been low since 1988. To the extent that recent price trends are discernible they have been generally favourable for hybrid maize adoption and the most likely causal factor has been the declining real price of fertiliser.

The overall decline in the nitrogen/maize price ratio reflects the gradual substitution of high analysis fertilisers. The shift in relative nitrogen price has increased the incentives for the use of fertiliser on maize, and because hybrids are more fertiliser responsive than local maize, has increased the incentives for the use of hybrids.

The initial fall in the seed/maize price ratio was more likely a response to large inventories held by NSCM after years of low hybrid use than a major cause of the subsequent upturn in hybrid adoption. Seed costs are in any case a relatively small proportion of the production costs of fertilised hybrid maize but do remain an important issue for the cash-constrained farmers in isolated rural areas.

To the extent that hybrid maize has been viewed as a cash crop, a decline in the relative price of an alternative cash crop such as groundnuts contributes to adoption. But the recent rapid uptake of hybrid seed has been too large, too sustained, and has been distributed over too many farmers to be primarily the result of farmers seeking alternative cash crops. Increasing home consumption of hybrid maize should further weaken the relationship of output prices to hybrid maize adoption in future years.

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9 Both Griliches (1957) and Knudson (1991) found that output and seed price did not explain the diffusion of hybrid maize and semi-dwarf wheat, respectively, in the US. Knudson did find that lower relative fertiliser prices affected the diffusion of semi-dwarf wheat.

10 For example, what is important is not whether or not the price of fertiliser is rising, but whether this price is rising faster or more slowly than the price of maize.

Table 4: Indices of input and output prices relative to the price of maize: 1980 = 100.

Year	Nitrogen	Maize Seed	Groundnuts
1970	-	-	84
1971	-	-	84
1972	95	-	94
1973	95	-	108
1974	175	-	94
1975	116	-	78
1976	116	-	78
1977	116	-	86
1978	116	-	129
1979	83	-	98
1980	100	100	100
1981	133	114	92
1982	97	72	106
1983	99	74	112
1984	101	80	118
1985	124	80	118
1986	124	85	118
1987	91	60	88
1988	73	46	69
1989	81	58	73
1990	90	71	73
1991	91	80	75
1992	83	82	69

Source: Calculated from data from Malawi Ministry of Agriculture and ADMARC, including data reported by Gulhati (1989); Williams and Allgood (1990); Sahn and Arulpragasam (1991).

All prices are divided by the ADMARC maize producer price and then converted to an index with the value in 1980 set at 100. The price of nitrogen is calculated from the price of nitrogen for each major source (S/A, CAN, and urea) weighted by the total amount of smallholder nitrogen obtained from each source in any given year. The price of seed is the ADMARC smallholder price for single-cross hybrid seed. The price of groundnuts is the ADMARC groundnut producer price.

PROJECTING RESEARCH BENEFITS

In this section, the adoption rates in Table 2 and other economic data are used to project diffusion paths for aggregate area under hybrid maize and calculate *ex ante* estimates of the rate of economic return to maize research under different scenarios.

Method

The method employed is the economic surplus approach, which generates an estimate of the average rate of return over the period of analysis (Norton and Davis, 1989). In each year, the increased per hectare benefit from using hybrids rather than local maize is multiplied by the total area under hybrids to estimate total benefits in that year. Costs of maize research are also estimated. The internal rate of return is the discount rate that makes the sum of discounted net returns (benefits minus costs) equal to zero.

The first step was to project diffusion paths. Non-linear least squares was applied to the adoption rates shown in Table 2 to estimate logistic curves for the future proportion of aggregate maize area under hybrid[11]. The

[11] The most commonly used of the S-shaped curves used to describe the diffusion of new technology, the logistic function is of the form:

six year period from 1987 to 1992 was used because during that period hybrid maize area increased continuously (at an average of 30 to 40 percent from one year to the next). Previously hybrid maize area had fluctuated at a relatively low level with no observable trend. Estimated curves were then modified to create the three scenarios pictured in Figure 1 and described below.

Diffusion Scenarios

The first scenario represents the potential impact of national maize research on dent hybrids only. The logistic curve was fitted only to the data points from 1987 through 1990 because in 1991 and 1992, semi-flint hybrids displaced some maize area that would otherwise have been planted to dent hybrids. Based on the logistic curve, the projected adoption ceiling is an estimated 27 percent of maize area. In other words, if adoption rates had continued to climb according to a logistic pattern fitted to data from the late 1980s, about one-quarter of Malawi's maize area would eventually have been planted to dent hybrids[12].

The second scenario represents the potential impact of national maize research on both dent and semi-flint hybrids, from a "pessimistic" perspective. Scenario II is "pessimistic" because, although the data and logistic function predict that adoption will reach 100 percent in 2011, we re-estimated the diffusion path by forcing the adoption ceiling to 50 percent[13]. Such a scenario could occur if unknown socioeconomic or institutional factors impede adoption. In this scenario, we also assumed that only 20 percent of maize area would be planted to dent hybrids because substitution of semi-flint hybrids for dent hybrids by some growers would lead to a lower ceiling adoption rate for dent hybrids than in Scenario I. Eventually, 30 percent of maize area would be planted to semi-flint hybrids and the remaining 50 percent in local varieties.

The third scenario represents the potential impact of national maize research on both dent and semi-flint hybrids, from an "optimistic" perspective. To err on the side of caution, the adoption ceiling was set at 75 percent of total maize rather than 100 percent, with the same estimation procedure used in Scenario II. Again an adoption ceiling of 20 percent was assumed for dent hybrids, implying an eventual adoption rate for semi-flint hybrids of 55 percent.

Other Assumptions

Using the chronology reported in the first section, four research time periods were defined by initial and terminal years. Initial years were set at either 1953, when the colonial programme began, or 1977, when the hybrid programme was restored. To mark the initial year as 1953 overstates the active years of maize breeding because it ignores the deterioration of breeding lines during the 1960s and the ten-year hiatus in the hybrid breeding programme. Marking the initial year as 1977 understates the active years of maize breeding because it omits the research experience of the colonial years entirely. Terminal years are defined as 1992 or 2012, meaning that benefit

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$$P = \frac{K}{1+e^{-(a+bt)}}$$

P is the proportion of aggregate maize area under hybrids, "t" is time, "K" is the ceiling rate of adoption, "a" is a parameter related to the initiation of the diffusion process, and "b" is a slope parameter associated with the speed of diffusion.

12 this estimate is not high given that in 1992/93, 17 percent of Malawi's total maize area was already planted to dent hybrids.

13 Ordinary least squares regression was used to force a lower than predicted ceiling, using the estimation method from Griliches' (1957) classic article on hybrid maize diffusion in the US.

streams end today or twenty years from today.

Other assumptions used in the analysis are summarised in Table 5. A growing population is assumed to counteract the downward pressure on maize prices that result from increased maize output. Yield levels are set at average levels recorded in the National Crop Estimates over the last decade. In calculating benefits, dent hybrids are assigned a price lower than semi-flint hybrids or local maize, reflecting their lower value to consumers. The costs of hybrid seed and fertiliser costs are deducted from their benefits, with input prices set at *unsubsidized* levels. Although much of the recent increase in hybrid area has been planted to an imported hybrid (NSCM41), national maize research was an essential precondition for developing an understanding of the performance of hybrid maize in Malawi and for the establishment of a seed company in the late 1970s. We assume that if there has been no national maize research, hybrid maize usage would have begun later (1985) and imported hybrids would have reached a ceiling adoption rate of 15 percent.

Costs of maize research are calculated for each year from 1953 through 1992 by dividing the number of maize researchers by the total number of agricultural researchers, and then multiplying by actual research expenditures reported by Pardey and Roseboom (1989)[14]. Costs include overhead (e.g. research station and administrative costs) as well as yearly operational costs for all maize research, but the benefits are only those resulting from hybrids (excluding OPVs). Finally, all costs and benefits were converted to 1992 levels using the GDP deflator before the internal rates of return were calculated.

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14 Researchers who were not full-time maize researchers were given a weight of 0.5. Where figures were not available from this source they were extrapolated from the closest contiguous years.

Table 5: Assumptions Used in Calculating Internal Rates of Return to Maize research in Malawi.

Variable	Assumed Level
Benefits (Hybrid Maize Only)	
Proportion of aggregate maize planted in hybrids	Scenarios I to III
Aggregate maize area	1.4 million hectares in year 2012
Population in 2002[a]	12,332,000
Maximum per capita consumption	230 kg/year
Maize yield	
Hybrid	2.8t/ha
Local	0.9t/ha
Maize price	
Semi-flint hybrid	1992 ADMARC buying price
Local maize	1992 ADMARC buying price
Dent hybrid[b]	85% of 1992 ADMARC buying price
Seed and fertiliser prices	unsubsidised 1992 prices
Initiation of adoption path with imported hybrids only	1985 (five year lag)
Ceiling adoption rate for imported hybrids only[c]	15 percent
Costs (all Maize Research)	
Per professional research officer	
1954-1964	1965-1969 average real level
1965-1984	1965-1984 actual real level
1985-1990	1980-1984 average real level
Research implementation	average costs per maize researcher do not differ from DAR average
Number of maize researchers[d]	full-time weight 1; part-time weight 0.5
Conversion factors to 1992 prices[e]	GDP deflator

Sources

[a] House and Zimalirana (1992), Population increases are assumed to counteract possible downward pressure on maize prices caused by increased output.

[b] Based on processing tests reported by Sibale (1988).

[c] Benefits from imported hybrids are deducted from total research benefits.

[d] GON; GOM/DOA; GOM/DAR.

[e] World Bank (1992); Reserve Bank of malawi (1992)

Results

Rates of return to hybrid maize research were calculated for each of the three impact scenarios. Several points emerge from the results (Table 6).

First using a 10 percent cutoff figure[15], rates of economic return to maize research are acceptable in all cases except under the implausible assumption that maize research was continuous from 1953 and benefits ended today. This is essentially the assumption underlying the conclusions reached by Kydd in 1989. Second, if only the period following the reinstatement of the hybrid programme in 1977 is considered, neither the length of the benefit stream nor the ceiling adoption rate affect the rate of economic return significantly. The insensitivity of results is produced by the interaction of (1) modest research costs, (2) a short lag from time-of-release to initiation of adoption, (3) the speed of adoption, and (4) the yield superiority of hybrids[16]. Similar rates of return have been reported in other studies of crop research[17]. Finally, internal rates of return for the hybrid programme alone would be higher than those reported in Table 2. Similarly, internal rates of return for the overall breeding programmeme would be higher if the contribution of improved open-pollinated varieties were included.

Table 6: Internal rates of return to maize research

Impact	Period from initiation of research to final benefits			
Scenario	1953-1992	1953-2012	1977-1992	1977-2012
I	4	9	63	63
II	7	15	64	64
III	7	16	64	64

CONCLUSIONS

The chronology of maize research in Malawi shows that despite changes in research strategies, Malawi's maize breeders have always emphasised flint character in addition to yield criteria by developing semi-flint hybrids or semi-flint OPVs. Adoption data show dramatic increases from the late 1980s. The economic rate of return to Malawi's maize research programme suggest that it is better characterised as a success than a failure. Since semi-flint character makes hybrids more acceptable to small farmers, the distribution effects of maize research are also likely to be positive. When future national and household food security in Malawi is valued more highly than is suggested by conventional internal rate of return calculations, the positive research impact of the hybrid maize programme is even greater.

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15 The World Bank often uses a 10 percent figure as acceptable in its project evaluation.

16 When internal rates of return are in the range of 60 percent, benefits 10 years from the initial period receive a weight of less than 1 percent. High rates of return in one sense signal a very short payback period.

17 Rates of return to agricultural research are summarised by Ruttan (1982), Pinstrup-andersen (1982) and Echeveria (1990). Relatively few such studies have been done for Africa, but recent work in progress, particularly at Michigan State University, suggests the range of estimates for African agricultural research does not appear to differ from those for studies done eslewhere.

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