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BIOTECHNOLOGY AND FARM SIZE IN KENYA

by

L.P. Mureithi and B.F. Makau

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PREFACE

Within the framework of the Technology and Employment Programme, this study is the fifth in a series on the potential socio-economic and employment effects of specific biotechnologies in developing countries. While this study focuses on the diffusion of biotechnology in Kenyan agriculture, the others broadly cover food and export crops, edible plant-oils processing, and the dairy and animal feed industries within a multidisciplinary framework of analysis using both micro- and macro-level data.¹

The objective of this study by L.P. Mureithi, Associate Professor of Economics at the University of Nairobi, and B.F. Makau, Science Secretary of the Kenya National Council for Science and Technology, is to evaluate the biotechnologies introduced for potato and tea in achieving the following national goals: (a) augmentation of the quantity and diversity of food supply; (b) increase in incomes; (c) generation of employment; and (d) boosting of exports.

This pioneering study sheds new light on the relationship of biotechnology to farm size and productivity, growth, employment and income distribution in Kenya.

The adoption of the new biotechnology² in the cultivation of potato doubles land productivity, labour-intensity and profitability and increases labour productivity by 24 per cent. Its contribution (value added) to national income is twice that of the traditional technology. Labour's share in total factor income is higher for the new technology adopters compared to the non-adopters. The relative efficiency (value added as a proportion of gross output) is also higher for the adopters.

On the basis of concrete empirical evidence, the study most convincingly demonstrates the developmental potential of small farm strategies both under a traditional agricultural setting and under dynamic conditions of technological change, the inverse relationship between farm size and productivity both for the traditional and the new biotechnology. The small farms, relative to large ones, use less capital, make a large contribution to value added and demonstrate stronger inter-industry linkages. The advent of biotechnology will certainly permit the pursuit of growth with equity.

Iftikhar Ahmed

¹ These include a conceptual piece, an overview of plant-oils processing, a comparative study between Mexico and the United States on impact of specific biotechnologies in the sugar and dairy industries, overall rural employment implications in China, the Philippines and Mexico, labour absorption in Malawi agriculture, and biotechnology's capacity to combat protein deficiency in Nigeria.

² The method commonly uses the apex of the plant for tissue culture. The cells are grown into plantlets in a special growth media under controlled conditions and are tested for quality, viruses and diseases. Multiplication and clonal development on a large scale follows.

BIOTECHNOLOGY AND FARM SIZE IN KENYA

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BIOTECHNOLOGY AND FARM SIZE IN KENYA

by

L.P. Mureithi and B.F. Makau

INTRODUCTION

Biotechnology may be broadly defined as the use of ideas and methods of science to study and explain the structure and processes of living organisms and the use of knowledge so gained to manipulate living organisms for social and economic objectives. The two components identifiable by this definition are: (1) study and explanation which constitute basic research as broadly understood; and (2) utilisation of that knowledge for socio-economic development - the applied and adaptive aspects of science.

However, it is necessary to be more specific when one is addressing a particular topic or commodity because, under the above broad definition, biotechnology has come to mean different things to different people - especially depending on the level of sophistication at which they are operating. Indeed to many scientists, especially those in the more developed countries, biotechnology implies operations at the cellular level such as genetic engineering. The other line of thought is that biotechnology is as old as traditional plant and animal breeding and can be traced to the early 1930s when Mendelian genetics began to be applied in practical ways to improve crop and animal production. It is our view that traditional plant breeding, tissue culture, cloning and cell manipulation constitute a progression of the same process. We take up the process at the level of tissue culture and examine its employment and incomes implications in potatoes and tea.

In Kenyan agriculture, there has been - over the years - work involving plant breeding, i.e. improvement and selection in maize, wheat, coffee, and other crops; cloning and tissue culture in tea, potatoes, flowers and various other plants; animal breeding, improvement and protection by such means as artificial insemination and vaccine production, respectively. For these purposes, research stations have been set up and an extension network instituted to encourage generation, adoption and diffusion of biotechnology with a view to furthering, inter alia, the following objectives: (a) augmentation of the quantity and diversity of food supply; (b) increase in incomes; (c) generation of employment; and (d) boosting exports.

The purpose of this study is to assess the extent to which the above objectives are being pursued through biotechnology applications in tea and potato.

POTATOES

History and economic importance

Potatoes were introduced into Kenya by European settlers from South Africa at the end of the nineteenth century (Ballestrem and Holler, 1977). By 1921 there were about 93 hectares, mainly grown by Europeans (Waithaka, 1976). Since then, the production of potatoes has rapidly risen to become an important subsistence crop mainly grown by Africans in smallholdings of up to two hectares. In 1979 there were 480,000 holdings growing potatoes in a total of 200,000 hectares in both pure and mixed stands (Homann, et al. 1979). This area rose to 260,000 hectares in 1982 (Majisu, 1982) and was estimated at 300,000 hectares with a total production of 500,000 tonnes in 1985 (ISNAR,

1985). In 1975, potatoes were contributing substantially to the national diet with a demand of 270,000 tonnes which is expected to rise to 828,000 tonnes in 1989 (see table 1).

The importance of potatoes, as a source of food, in relation to other crops is shown in table 1. In table 2, we present the percentage of smallholders growing various crops in 1985. It can be seen from table 2 that although the percentage of smallholders growing potatoes was well below that of other food crops, such as maize, it was well above that of important cash crops such as coffee, tea, pyrethrum and cotton.

Table 1: Estimated per capita food consumption and projected demand

	Average annual per capita consumption			Total demand	Estimated total demand
	Rural ¹	Urban ²	Total	1975	1989
Selected food items	Kg			'000 MT	'000 MT
Wheat - bread and flour	9.6	31.1	12.1	163	493
Rice	1.4	6.1	2.0	26	90
Maize - flour (grain)	114.2	70.2	113.3	1 508	3 514
Other cereal - flour	18.5	5.9	16.8	230	563
Irish potatoes	20.6	14.7	19.9	270	828
Other roots	66.0	16.2	60.0	814	-
Sugar (raw and cane)	11.6	18.9	12.4	169	571
Pulses (beans)	11.3	10.5	11.2	151	344
Vegetables	17.8	52.6	22.0	298	-
Bananas	11.5	20.2	12.5	170	-
Other fruits	16.4	23.0	17.2	233	-
Vegetable oils	0.8	2.3	1.0	14	-
Animal fats and oils	0.1	1.9	0.4	5	-
Butter	0.1	1.7	0.3	4	-
Milk	48.7	41.7	47.8	649	2 058
Beef	6.8	11.9	7.4	100	314
Other meat	5.9	6.5	6.0	81	-
Eggs	0.8	2.1	0.9	12	-
Fish	1.7	7.9	2.5	33	-

¹ Total rural population (1975, excl. pastoralists): 11,936,000.

² Total urban population (1975), 1,634,000.

Source: International Service for National Agricultural Research (ISNAR), Kenya agricultural research strategy and plan - Vol. 2: priorities and programmes (The Hague, 1985).

Table 2: Percentage of smallholders growing various crops

Crop	Smallholders (%)
Local maize	86
Hybrid maize	50
Beans	69
Potatoes	32
Sorghum	30
Coffee	27
Tea	12
Pyrethrum	9
Cotton	9

Source: ISNAR, op. cit.

In Kenya, potatoes are grown mainly in the Central, Eastern and Rift Valley Provinces at altitudes from 1,600 metres to 2,700 metres where there is adequate rainfall and low temperature. Between these altitudes is to be found nearly 12 million hectares of high potential land on which, apart from other crops and pastures, potatoes can be grown. Various varieties are grown. These have different maturity, yield and disease-resistant characteristics.

Research and technological trends

Considerable attention has been paid to the selection and introduction of high-yielding disease-resistant potato varieties as well as pertinent agronomic research. Some attention has also been paid to marketing and storage.

The selection programme started in the mid-1960s when some lines were developed in Scotland and brought to Kenya for further screening and testing. This resulted in varieties such as Roslyn Eburru (B53), Roslyn Sasumua (C52) and Roslyn Chania (C53). Roslyn Eburru has now become one of the major varieties grown in Kenya. A breeding programme was started at the National Agricultural Laboratories in the late 1960s aimed mainly at varieties resistant to late blight and, to a certain extent, to bacterial wilt and viruses. At the same time that these developments were taking place, new varieties were introduced directly from Europe - the most important of these being Anett, Feldeslohn and Desiree. Other important varieties which were introduced from outside Kenya but whose history is rather obscure are Kerr's Pink (Meru) and Dutch Robijn (Ngolof). More recent emphasis is now on selections from the International Potato Centre (CIP) in Lima, Peru. Some of the CIP selections are already showing promise as potential varieties.

At the same time that the above-mentioned breeding work was going on, agronomic trials have been undertaken. These trials have resulted in the characterisation of the varieties and their potential for various ecological zones in Kenya as well as recommendations on various cultural practices. Also going along with these activities in research was seed inspection service as well as clone and certified seed development which also started to take shape in the late 1960s. All in all a total of 56 varieties have been identified as existing in Kenya.

Institutionally, the breeding work in Kenya was initially undertaken at the National Agricultural Laboratories in Nairobi, including research on bacterial wilt and virus diseases. The raising and screening of seedling and the multiplication of healthy stock is undertaken at the National Potato Research Station at Tigoní. A parastatal organisation, the Agricultural Development Corporation is mandated to ensure the growing of certified seed potatoes - most of which it sells through the Kenya Grain Growers' Co-operative Union - while the National Seed Quality Control Station at Nakuru undertakes the inspection of the certified seed. Agronomic research was undertaken at the National Horticultural Research Station at Thika but this has now been brought to the National Potato Research Station.

Excluding the traditional plant breeding, the main biotechnological applications in Kenya are meristem (tissue) cultures leading to clonal multiplication to certified seed. Currently, tissue culture work on potatoes is undertaken at the National Plant Quarantine Station (NPQS) of the Kenya Agricultural Research Institute at Muguga. Its mission in this regard is to screen and multiply imported material such as those from CIP; to clean local material for fresh clones; to undertake limited multiplication of material to meet Kenya's needs; and to preserve the germplasm received.

The station was established in 1954 and it served the East African community in plant quarantine until 1977 when the community broke up. However, it does still serve the rest of Africa with regard to material from CIP.

The current method commonly used at the station utilises the apex of the plant for tissue culture. Material may be brought in the form of tubers or seeds or seedlings and/or meristem tissues as is the case with CIP material. The material is germinated (from seeds, tubers or meristem tissue) and small pieces of apex tissues are removed and grown in special growth media under controlled conditions. At the same time, the tissues of the germinated plant are tested for diseases - the most common method for testing the viruses at the station being the ELISA serological method. The plantlets developed from the apex tissue are tested further. If found to be free of viruses, multiplication is undertaken on a larger scale through the same method and the resulting material is supplied to the National Potato Research Station at Tigoní for clonal development.

The National Potato Research Station (NPRS) was acquired as a farm (formerly called Mthanga farm) in 1967. In 1972 it was designated a research station. It has developed as a disease-free centre for raising and screening seedlings for blight resistance and for the multiplication of healthy stocks of established varieties and new promising cultivars. In more recent years, it has incorporated a research programme in breeding, pests, agronomy, processing and socio-economics. However, to date maintenance or clonal breeding and the provision of enough seed for foundation stock remains the largest programme at the station. This work is undertaken both at the main station at Tigoní and at sub-stations in South Kinangop, Meru and Molo. This makes it possible to obtain information from different ecological zones and, at the same time, ensure a supply of adequate foundation stock.

Foundation stock is multiplied by large-scale growers and once the seeds have qualified after inspection they are called basic seed. These are sold to farmers who wish to produce certified seed. Table 3 gives the hectareage of certified potato seeds grown since 1979.

Table 3: Production of certified potato seeds

Year	Hectares approved
1979/80	120
1980/81	467
1981/82	414
1982/83	362
1983/84	280
1984/85	364
1985/86	444

Source: Records at the National Seed Quality Control Centre.

Indirect credit to large potato growers and the occasional certified seed outgrowers is in the form of certified seed, chemicals and gunny bags, the cost of which is subtracted from the sale proceeds. Grading, storage and marketing is done free of charge for the farmers participating in the ADC outgrowers' schemes.

The ADC has good storage facilities where up to 2,250 tonnes (45,000 bags) can be stored for up to six months at about 4°C. This cold storage started operating in 1985. The ADC markets the potatoes through the Kenya Grain Growers' Co-operative Union (KGGCU) which has agricultural inputs and products outlets throughout the country. However, the KGGCU does not itself buy to sell. It only stocks the potatoes for the ADC and the latter has ultimate responsibility for the stock, whether or not they sell.

The potato sample survey

We purposely selected 33 farms growing potatoes in 1986, bearing in mind the potato zones of the small-scale and large-scale farming areas. For the former, we chose Kabaru on the slopes of Mount Kenya and Othaya on the slopes of the Nyandarua ranges, while for the latter, Molo and Mau Summit in the Rift Valley highlands proved ideal. The majority of the potato farms are small, being under two hectares. Anything in excess of ten hectares is large and so between two and ten hectares was classified as medium size. Data was gathered through direct interviews using a structured questionnaire.

The diffusion of innovation

The extent of the adoption of clonal certified seed potatoes can be gauged by the fact that 27 per cent of all the farms in our sample had certified potato fields as pure stands while 36 per cent of them had mixed (certified and non-certified) stands. The crude adoption rate, i.e. the proportion of farmers adopting clonal certified seeds, is positively associated with farm size. Taking the mixed fields, the adoption rate was 25 per cent for the small-scale farms, 46 per cent for the medium-size ones and 50 per cent for the large-scale farms (table 4). The propensity to adopt certified seed is not systematically related to education, since the average length of education is 7.3 years for small-scale farmers, 4 years for medium-scale farmers and 6.5 years for large-scale farmers.

The intensity of adoption, i.e. the proportion of potato area brought under clonal certified seeds, increases from 21 per cent in the small farms to

37 per cent in the large farms. This is possibly due to the fact that the Agricultural Development Corporation's potato project deals quite aggressively with the large-scale farmers, some of whom are used for purposes of field multiplication of certified seeds. It is instructive, however, that the adoption intensity declines with farm size - it being 17 per cent in the medium-scale farms - when large farms are excluded. We conclude, therefore, that the intensity of adoption is negatively associated with farm size, other things being equal.

Table 4: Adoption of innovations: Potatoes in Kenya^a

Farm size	Percentage of farms with			Percentage of cropped areas with		
	Certified crop	Non-certified crop	Mixed field	Certified crop	Non-certified crop	Mixed field
Small	38	38	25	21	48	28
Medium	15	38	46	17	46	36
Large	25	25	50	37	12	51
All	27	36	36	28	28	42

^a Source: Field data.

Income generation and distribution

As a business, a farm generates income in cash and in kind. Total output - taken to include the market value of potatoes sold, fed to livestock or used for own consumption - amounted to Ksh.37,269 per hectare of certified potatoes in small farms while the same area yielded Kshs.20,641 if planted with non-certified seeds. For large farms, the yield was Ksh.29,273 for certified and Ksh.13,265 for non-certified potatoes.

The following should be noted. Firstly, the gross output per unit area is higher for certified potatoes than for the non-certified variety, whichever farm size category is considered. This is to be expected since the certified varieties of potatoes yield a larger physical output per hectare than the non-certified varieties, in our case 36,721 kilograms versus 14,406 kilograms. Secondly, gross output per hectare declines as farm size increases. This collaborates the "large body of evidence that suggests that small farmers make more efficient use of available land than large farmers" (Hayami and Ruttan, 1985, p. 340).

In table 5, we present statistics on production, inputs, gross margins and value added. Intermediate inputs are seed potatoes, fertilisers and other chemicals such as insecticides, pesticides, weedicides and fungicides. We also include in this category transport for both the intermediate material inputs and potatoes. Intermediate inputs, therefore, largely represent the extent to which the potato industry patronises other sectors and to that extent stimulates them to produce further output, generate more employment, etc. Taken as a proxy for backward linkage, intermediate inputs per hectare are higher for certified than for non-certified potatoes.

Table 5: Output, input and surplus
(shillings per hectare)

Type of crop	Certified potatoes				Non-certified potatoes			
	Small	Medium	Large	All farms	Small	Medium	Large	All farms
Gross output (1)	37 269	25 580	29 273	33 210	20 641	21 744	13 265	16 362
Intermediate input (2)	4 171	5 004	1 774	3 553	3 101	2 433	2 621	3 008
Equipment usage (3)	289	484	1 135	867	157	385	556	426
Labour costs (4)	3 621	9 403	7 246	7 974	2 925	3 756	2 164	3 012
Operating costs (2+3+4) = (5)	8 081	14 891	10 155	12 394	6 183	6 574	5 341	6 446
Operating surplus (profit) (1-5)	29 188	10 689	19 118	20 816	14 458	15 170	7 924	9 916
Value added (1-2)	33 098	20 576	27 499	29 657	17 540	19 309	10 644	13 354

Source: Field survey.

Capital equipment in potato production includes forked and plain hoes, pangas (machetes), sprayers, debes (tins) and an occasional tractor. We assumed that the useful life of such equipment is an average of ten years. On this basis, 10 per cent of the value of the equipment was taken to be consumed in potato production every year, i.e. the flow of capital services. As expected, capital usage is less in smaller-scale farms than in larger ones which tend to be more mechanised. As table 6 reveals, certified potatoes exert greater demand for capital usage than non-certified potatoes.

Table 6: Distribution of incomes and land

Percentage of sample	Share of incomes		Percentage of land area
	Certified	Non-certified	
Poorest/smallest (40)	3	7	3
Middle (30)	8	15	7
Richest/largest (30)	89	78	90
Concentration ratio	8	4	9

Source: Field survey.

Labour costs were calculated for hired and family labour, the latter being valued at the going wage rate for hiring farm workers, i.e. the valuation is on the basis of opportunity cost. In general, it takes more work-hours to produce clonal potatoes, particularly due to the cultural practice of ridging before planting certified seeds - a practice that is not universally observed in non-certified potato cultivation.

The total costs of operation per area of cultivated land are higher with innovation than without, just about double. It is true also that the profits in such enterprises are in roughly the same order of magnitude. Yet, the fact that one has to incur the cost prior to drawing the benefits might act as a budgetary (financial) constraint to innovation. This could explain the somewhat reluctant manner with which small farmers innovate, as reflected in table 5 by the relatively low land area devoted to clonal certified potatoes. We therefore feel that there should be in position a credit scheme to enable farmers to adopt proven biotechnical innovations. Such a scheme could use improved potatoes as an anchor crop and would cover, not just the acquisition of seeds and intermediate materials, but also the cost of labour since "cash flow constraints especially hinder fertiliser use and labour use" (IFPRI, 1986, p. 24).

The average wage rate ranges from Ksh.19 per work-day in medium-size non-certified potato farms to Ksh.29 in large-scale certified potato farms. The statutory daily minimum wages range from Ksh.17 for rural areas to Ksh.31 for municipalities. Hence, labourers deployed on potato production are no worse off, whether the labour demand is seasonal or casual. A further indication as to whether one can make money in potato activity is gauged by the farm revenue and the owner's operating profits. With gross revenue at an average of Ksh.33,210 for a hectare of certified potatoes, this compares favourably with other possible agricultural activities such as coffee at

Ksh.29,780 and vegetables at Ksh.18,260 per hectare in 1984 [Kenya(a), 1986, p. 64]. If the farm operator opted to be employed in a modern sector job, the average wage earning would have been around Ksh.20,958 in 1985 [Kenya(b), 1986, p. 42] while foregoing Ksh.20,816 as clear profit for growing one hectare of improved potatoes. Clearly then, the growing of improved potatoes plays a crucial role in the alleviation of poverty and warding off rural-to-urban migration - all salutary impacts on the employment problem.

Value added is gross output net of intermediate inputs and gives the earnings by the various factors of production - land, labour, capital and entrepreneurship. It is part and parcel of National Product, i.e. national income avoiding double counting. From table 5, it is clear that the contribution to national income is higher with new biotechnology than with the traditional technology.

Aside from the absolute level of incomes, the distribution of income is important. To assess this, we took the ratio of the share of gross income by the richest 30 per cent of the farmers to the share by the poorest 70 per cent of the farmers as the measure of concentration. This turned out to be eight for clonal certified potatoes and four for non-certified potatoes, as is shown in table 6. It would appear that the "Green Revolution" effect is being felt, whereby the introduction of modern varieties of crops acts "as a source of inequity in income distribution" (Hayami and Ruttan, p. 337).

Underlying the unequal distribution of income is uneven distribution of land. The smallest 70 per cent of the farms accounted for 10 per cent of the land area so that the coefficient of concentration of land ownership among potato farmers is estimated at nine; that is, the sharing of this productive asset is even more unequal than its fruits. Perhaps this pushes the smaller farms to be more intensively cultivated to excel in productivity per land area in an attempt to catch up with their larger counterparts. While potato farmers may not be typical of farmers and our sample may be too small for very firm conclusions to be drawn, our data is nevertheless suggestive of highly skewed distribution of incomes and land such that "the gains in production" arising from modern-variety technology "have been offset by losses in equity" (Hayami and Ruttan, p. 329).

Employment potential

In this section, we shall examine the employment implications of the introduction of improved varieties of potatoes. In empirical economic literature, the share of wages in value added has been shown to be an approximate measure of labour intensity (Lary, 1968). On this score, certified potatoes as a group, at 27 per cent, fare better than the traditional varieties at 23 per cent and our results support the hypothesis by Bhattu that "biological technology, in general, is not known to be labour substituting in itself" (Bhattu, 1978, p. 20).

An impression on the prevailing average capital labour ratio is obtained by glancing at table 7 where capital use per work-day is given. This reveals the characteristic positive relationship between capital intensity and farm size, and therefore the decreasing relative ability to create jobs as farms expand. This phenomenon in mechanical technology applies equally in certified potato operation as in non-certified fields, so that, on the average, capital-labour ratio is the same. To the question posed by Hayami and Ruttan (p. 341) as to whether modern-variety technology promotes mechanisation, our answer would be: no.

Table 7: Labour intensity and factor productivity in potato farming

Type of crop	Certified potatoes				Non-certified potatoes			
Size of farm	Small	Medium	Large	All farms	Small	Medium	Large	All farms
Value added to gross output (%)	89	80	94	89	85	89	80	82
Wages in value added (%)	11	46	26	27	17	19	20	23
Work-days per hectare (No.)	181	446	253	301	143	200	97	144
Capital use per work-days (Ksh.)	2	1	5	3	1	2	6	3
Labour productivity (kg/work-day)	124	27	170	124	61	67	193	100

Source: Field survey.

For a typical farmer, land is a fixed factor of production in the short run, and highly inelastic in supply even in the long run. For Kenya as a whole, it is fixed; it is therefore scarce and exerts an effective constraint. It should be of interest to see how use of improved seed varieties enables it to generate employment. Measured in terms of labour-land ratio, i.e. work-days of labour employed per hectare, certified potato farms are typically better at employment creation than their less innovative counterparts.

In its enhanced labour absorption, does improved potato cultivation operate at the expense of productivity? No. Because physical labour productivity (kilograms per work-day) is actually 24 per cent higher in certified potatoes taken together than in non-certified potatoes. Again, since "what a rise in the proportion of value added (to gross output) reflects is a lower input of materials for producing the same output which is one of the principal objectives of technological improvements" (Bhatty, p. 78), relative efficiency as measured by this criterion puts certified clonal potatoes ahead of the unimproved crops.

We conclude that the introduction of improved varieties of potatoes leads to more labour absorption on the farms and that this happens simultaneously with gains in factor productivity and relative efficiency. Incomes are improved by such an innovation, and although its distribution could well be more unequal the multiplier effect of income and employment to the economy is greater.

TEA

History and economic importance

Tea was first planted in Kenya at Limuru in 1903 (Kenya Tea Growers' Association, undated). By 1930 Kenya's annual tea production was approaching 1 million kilograms and the current production exceeds 140 million kilograms per year. Kenya is the world's fourth largest tea exporter, accounting for 11 per cent of the world's tea exports and well over half that exported from Africa. After coffee, tea is the second most important foreign exchange earner. Table 8 gives the land area planted under large-scale and small-scale farms, together with total production and the value of exports and local sales from 1980 to 1985. It can be seen from the table that acreage and production have been increasing steadily over these years.

Table 8: Tea production: 1980-85

	1980	1981	1982	1983	1984	1985
Total area (ha)	76 541	78 896	81 082	81 536	83 372	83 824
Percentage area smallholder (ha)	62.2	66.8	67.5	67.4	67.8	67.4
Total production (million kg)	89 893	90 941	96 033	119 738	116 172	147 094
Total export (million kg)	74 799	75 500	80 371	100 645	911 989	119 689
Value of export Ksh million)	58 000	61 093	77 882	123 420	189 478	N/A
Local sales (million kg)	13 649	14 495	13 980	15 172	14 390	17 014

NB: Exports and local sales for any one year include carry-over stocks from previous years.

Source: Ministry of Agriculture, Nairobi.

On the relative importance of tea in comparison with other crops we return to table 2, which indicates that in 1985 more than one in every ten small-scale farmers grew tea on their farms. The crop is thus indicated as being of great importance to the nation in terms of the generation of income, foreign exchange and employment.

Research and technological trends

Research in tea is undertaken by the Tea Research Foundation (TRF) of Kenya based at Kericho. The selection of new clones is also undertaken privately by some large-scale farmers and also by the Kenya Tea Development Authority.

The TRF was initially founded as the Tea Research Institute of East Africa in 1951, servicing the members of the former East African community composed of Kenya, Uganda and Tanzania. When the community broke up in 1977, the Foundation facilities in Kenya reverted to exclusively Kenyan facilities.

The TRF is owned by the Tea Board of Kenya and its main objective is "to promote research into, and to investigate problems relating to tea and such other crops and systems of husbandry as are associated with tea throughout Kenya, including the productivity, quality and suitability of land in relation to tea planting; and on matters ancillary thereto" (Tea Research Foundation, undated). The TRF is therefore concerned with the study of all aspects of production, from site selection and land preparation to the packing of the finished product aimed at improving yields and quality.

The TRF is mainly funded by a cess contributed by the tea growers and is a fine example of the funding of research by farmers. It is also an implicit specific tax for the funding of research. Large investments in research are made by the tea growers through the TRF and through their own private efforts. Thousands of small-scale tea growers have benefited immensely from the research efforts of the TRF under the tea expansion programmes of the Kenya Tea Development Authority (KTDA) which looks after the tea industry under small-scale production. The KTDA programmes are themselves one of the world's leading examples of agricultural management for small-scale production (Bhatty, pp. 26, 98, 157).

Biotechnological applications

The major thrust in biotechnological applications in tea in Kenya is in the area of clonal development and vegetative propagation. The early propagation of tea was through the use of unimproved seed as a source of planting material. However, the use of seed resulted in high variability in various characteristics among individual plants. The programme of clonal development was started at the TRF and in some individual plantations to reduce this variability. This effort has resulted in various clones which have uniform or less variable characteristics and which give superior yields and quality.

As a result, large plantations which were wholly planted with seedling material began a steady programme of replacing and filling with clonal material. To date, about 10 per cent of the large plantations are now planted with clonal materials and any new additions or replacements are always planted with clonal materials. The small-scale farms, all of which started after the initiation of the clonal development programme, are all planted with clonal materials. The tremendous expansion of tea production in Kenya in acreage and yields - especially small-scale production - owes its performance, at least in part, to clonal development and rapid vegetative development work.

A clone takes 12 years to select, develop and test. After this, elite cuttings are used for rapid vegetative propagation methods and this supply becomes generally available to farmers.

The principal tea-growing areas of Kenya lie between 1,500 and 2,200 metres above sea level, in areas enjoying between 1,200 and 1,700 mm. of rainfall per year, with an all-year cool, almost temperate-like climate. Hence the range of environmental conditions under which tea is grown is quite narrow, as the tea plant itself is sensitive to changes in environmental conditions.

The data for tea

A structured questionnaire was administered to 39 tea farms. These included large-scale estates in the Kericho district of the Rift Valley province and in the Limuru area of Kiambu district in the Central Province, where tea was introduced prior to Kenya's independence in 1963; and also small-scale farmers from Othaya in the Nyeri district and Githunguri in the Kiambu district who began growing tea under the patronage of the Kenya Development Authority (KTDA) set up in 1964 for the purpose of promoting tea growing in erstwhile non-scheduled areas.

On the basis of information gleaned from various bodies in the tea industry we grouped tea farms into three classes: small - up to 3 hectares in area; large - in excess of 20 hectares; and medium - in between the above two. Detailed information was sought for the year 1986. Bearing in mind that human recall on data - particularly for small-scale farmers who generally keep no written records - would tend to diminish with time, we focused mostly on the previous year.

The KTDA introduced improved tea varieties right from the beginning so that - in general - smaller tea farm operators grow relatively more recent clone vintage than the larger estates, which - again in general - grow the more traditionally bred tea varieties. However, although tea is a perennial crop which could sustain production for decades on end - and which it would be agonising therefore for the farmer to cut down once planted - some plantations have found it wise to replace their seedling-based crops with clonal-based crops. They also invariably plant any newly expanded tea areas with improved varieties such that the proportion of area grown with improved clonal tea has risen from about 9 per cent in 1965 to about 19 per cent in 1986.

This substitution in favour of clonal tea will continue so long as the farmers perceive - as they do - that clonal tea grows faster and produces better quality and yields more quantity of tea per land area. For the time being, however, the adoption rate and the adoption intensity of clonal tea must be reckoned to be highest in small farms and lowest in large farms. Most of our conclusions on comparative performance are based on this premise.

Tea output can be measured in monetary terms as the amount of money paid to the smallholder farmers by the KTDA which procures the tea output. It therefore excludes the processing and marketing costs which the KTDA deducts from its sales on behalf of its clients. Kenyan tea is sold in bulk at an auction market in Mombasa, Kenya, which is intimately linked to international commodity markets, particularly the London tea auction. To be comparable, tea output by the plantations which have their own tea-processing plants and do their own bulk selling, was adjusted for factory and transport costs. Therefore tea output is, for our purpose, calculated as its value at farm gate.

Income generation and distribution

A glance at table 9 indicates that output per hectare is largest in the case of small farms, suggesting the intensification of land use as farm size decreases. This is confirmed by the greater application of intermediate inputs - fertilisers, insecticides, etc. - as improved varieties of tea are grown. As expected, small farm operators use minimal capital vis-à-vis large farms, if only because workers in large estates tend to use sickles rather than nail-pick tea as is commonly done in small farms. Average wages per work-day range from Ksh.16 in large farms to Ksh.21 in small farms while profits and value added are greater in the small farm sector.

Table 9: Input, output, value added and profits
(shillings per hectare)

Farm size	Small	Medium	Large	All
Total output (1)	28 674	26 210	26 635	27 363
Intermediate inputs (2)	1 533	1 156	983	1 124
Equipment usage (3)	26	5	40	16
Labour costs (4)	3 665	6 380	9 363	5 604
Operating costs (2+3+4) = 5	5 224	7 541	10 386	6 744
Profits (1-5)	23 450	18 669	16 249	20 619
Value added (1-2)	27 141	25 054	25 652	26 239

Source: Field survey.

From the foregoing, it is clear that earnings by the factors of production, labour and entrepreneurship are superior in smaller farms, but that all cases compare very favourably with alternative viable undertakings, for example, coffee at Ksh.29,788 per hectare per year (Kenya(b), 1986, p. 63). As in the case of potatoes, sectoral linkages (due to the stimulating effect of purchasing intermediate inputs) are strengthened and contribution to national income (value added) is increased by the introduction of improved clonal tea varieties.

The resultant income distributioun is shown in table 10 where the concentration indices - calculated as the share in income by the richest 30 per cent of the farmers relative to the share by the poorer 70 per cent - are given. With concentration ratios of between two and three for large and small farms, respectively, it would appear that the distribution of income is not disparate, though this conclusion is a bit weak when rapid adopters of improved tea varieties (small farm operators) are considered. To some extent, this consideration supports the Green Revolution effect observed earlier in the case of potatoes. It also supports the findings of a study covering the period 1974-75, that the Gini coefficient at 0.59 for income from tea east of the Great Rift Valley in Kenya (mostly small-scale farms), is considerably higher than the Gini coefficient at 0.47 which obtains for tea incomes west of the Rift (where most of the large estates are located). These calculations were done by J.L. Lijoodi and H. Ruthenberg (Clayton, 1983, p. 45).

Table 10: Distribution of income among tea farmers

Percentage of income	Share of income in	
	Large estates	Small farms
Poorest (40)	11	10
Middle (30)	29	15
Richest (30)	60	75
Concentration ratio	2	3

Source: Field survey.

Impact on employment

From table 11, we find that small-scale tea production is not particularly labour intensive - either as measured in terms of wages share in value added or in terms of work-days deployed per hectare of land. This could be because of the tendency for small farm operators to rely almost entirely on family labour, there being little labour available for hire as everyone in the neighbourhood is busy working on their shamba (farm, plot, parcel). Large estates, on the other hand, almost invariably have a standing hired labour force and access to casual workers who seek part-time or seasonal work. With the limited labour available to small farmers, they tend to spread it among the many farm activities such that the few allocated to tea work with deliberate speed so that the work-days expended are relatively few.

Table 11: Factor productivity and labour intensity

Farm size	Small	Medium	Large	All
Wages share in value added (%)	13	25	36	21
Work-days per hectare	172	314	587	350
Capital use per work-day (Ksh.)	0.05	0.02	0.07	0.05
Labour productivity (Sh. per work-day)	167	83	45	78
Value added to gross output (%)	94	95	97	96

Consequently, labour productivity is considerably higher in the small-scale tea farms than in the larger ones, and this is in spite of the almost negligible utilisation of capital equipment in tea farming. But looking at the proportion of value added to gross output, none of the farm sizes has an over-riding advantage from the point of view of this measure of relative efficiency.

Our analysis leads us to conclude that, while total factor productivity is rather high in the tea sector, and that in the small-scale farms land and labour are relatively more productive, labour intensity is considerably lower in small farms so that direct labour employment is unlikely to be augmented by the introduction of improved tea crop varieties to small farms.

From the preceding statement two corollaries come to mind. Firstly, there is a clear trade-off between employment creation and productivity. Secondly, the greater contribution to output by small-scale tea farms - per land area and per work-day - suggests that the indirect employment creation through the expenditure multiplier effect would be considerable, so that total employment creation would turn out to be far more with the introduction of improved varieties of tea than without.

CONCLUDING REMARKS

Improved varieties are unequivocally superior to traditional crops in terms of production and income generation. Our study revealed the mixed direct employment effect of modern varieties (MV), it being clearly higher in the case of potatoes but ambivalent in tea. However, when the indirect employment generated by increased income is taken into account, the total employment effect of MV crops exceeds the non-MV ones.

Comparing the two crops analysed, income per land area is greater for potatoes than for tea; so also is employment. But the resultant income distribution is more unequal in potato than in tea cultivation, though in both cases support is rendered to the contention that "the introduction of MV technology into a community in which resources are very inequitably distributed tends to reinforce the existing inequality" (Hayami and Ruttan, p. 338). Tea provides a steady demand for labour all the year round while potatoes are grown in two seasons per year. Potatoes are more demanding of intermediate inputs but, being seasonal, can be operated on a get-in-get-out basis - thus allowing for a quick entrepreneurial reassessment of the operational situation.

Almost universally, farmers complained of the high cost of certified potato seeds. While in the long term the Agricultural Development Corporation should find ways and means of lowering its sale price for seed potatoes, e.g. by more efficient operation and reduction of marketing margins, a credit scheme could immediately be put into practice for the acquisition of certified seeds, and other inputs. This could be facilitated by the formation of farmers' co-operative societies to deal in potatoes.

The marketing of tea is well handled by the Kenya Tea Development Authority for small farm operators and the Kenya Tea Growers' Association for the plantation sector. There is a need to streamline the marketing of potatoes, possibly through the co-operatives which could build storage facilities, foster canning of the crop and explore the possibilities of further processing into industrial and consumptive spirits, alcohol and starch.

Aside from serving as an animal feed (pigs, cattle), potatoes are an important source of carbohydrates, minerals and vitamins - thus serving as a vital component in national food security (Alvares in Terry, et al, p. 67). Tea is an important earner of foreign exchange. All these factors underline the socio-economic importance of both tea and potatoes.

The study furnishes concrete empirical evidence in support of the inverse relationship between farm size and productivity - both under the traditional and the new biotechnology in potato and tea. In all these cases, the small farms relative to large ones use less capital, make a larger contribution to national income and demonstrate stronger backward linkages to agricultural input suppliers.

Due to higher profitability and better financial capacity to bear the higher costs of investments associated with the new technology, large farms tend to pioneer the adoption of the new technology. It is also clear that the advent of biotechnology into an agrarian system in which land is unequally distributed (the smallest 70 per cent of the Kenyan farms accounted for a meagre 10 per cent of the country's land area) tends to reinforce the existing inequality. In this respect the Kenyan experience certainly is a close parallel to the experience of inequality created by the Green Revolution in Asia.

This study, therefore, provides important evidence to the policy-makers about the developmental potential of small farm strategies both in a traditional agricultural setting and under dynamic conditions of technological change. In addition to growth, such a strategy enhances aggregate employment and promotes more equitable distribution of income. While this will help economise on the use of capital, it will help achieve higher output per unit of the increasingly scarce resource - land - given the current population explosion in Kenya. Clearly, the technocrats' implicit assumptions of the technological superiority of the large farms is unsupported by the evidence. Possibly this explains why the Kenyan Agricultural Development Corporation's

potato project deals quite aggressively with the large-scale farmers, some of whom are used for the purposes of field multiplication of the certified (cloned) seeds.

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