WORLD EMPLOYMENT PROGRAMME RESEARCH

Working Paper

Technology and Employment Programme

**BIOTECHNOLOGY TRENDS:
A THREAT TO PHILIPPINE AGRICULTURE?**

by

Saturnina C. Halos

35424

Working papers are preliminary material circulated to stimulate discussion and critical comments.

January 1989

Copyright © International Labour Organisation 1989

Publications of the International Labour Office enjoy copyright under Protocol 2 of the Universal Copyright Convention. Nevertheless, short excerpts from them may be reproduced without authorisation, on condition that the source is indicated. For rights of reproduction or translation, application should be made to the Publications Branch (Rights and Permissions), International Labour Office, CH-1211 Geneva 22, Switzerland. The International Labour Office welcomes such applications.

ISBN 92-2-106976-1

First published 1989

The designations employed in ILO publications, which are in conformity with United Nations practice, and the presentation of material therein do not imply the expression of any opinion whatsoever on the part of the International Labour Office concerning the legal status of any country, area or territory or of its authorities, or concerning the delimitation of its frontiers. The responsibility for opinions expressed in signed articles, studies and other contributions rests solely with their authors, and publication does not constitute an endorsement by the International Labour Office of the opinions expressed in them. Reference to names of firms and commercial products and processes does not imply their endorsement by the International Labour Office, and any failure to mention a particular firm, commercial product or process is not a sign of disapproval.

ILO publications can be obtained through major booksellers or ILO local offices in many countries, or direct from ILO Publications, International Labour Office, CH-1211 Geneva 22, Switzerland. A catalogue or list of new publications will be sent free of charge from the above address.

PREFACE

Within the framework of the Technology and Employment Programme, this study is the fourth in a series on the potential socioeconomic and employment effects of specific biotechnologies in developing countries. While this study focuses on the impact of biotechnology developments on the rural poor of the Philippines, the others broadly cover food and export crops, edible plant-oils processing, the dairy and animal feed industries, agriculture and agro-industries within a multi-disciplinary framework of analysis using both micro and macro level data.¹

This study by Ms. Saturnina C. Halos of the Natural Sciences Research Institute, University of the Philippines, examines the following questions:

- (a) Which of the current international developments in biotechnology will affect the world market for Philippine major export crops, such as sugar, coconuts and fruits?
- (b) How are the current biotechnology programmes in the Philippines relevant to the rural poor? Are existing extension/technology transfer structures suitable for the dissemination of appropriate biotechnologies to the small farmers?
- (c) What are the nature, socioeconomic effects and potential of the specific biotechnologies being locally developed?
- (d) Are existing trends, programmes and structures in local R&D sufficient to propel Philippine agriculture into the arena of the bio-revolution?

The study concludes that biotechnology constitutes another cost-reducing tool for the corn growers in the developed countries, increasing their competitive edge and reducing world prices of corn. In the event corn import is liberalised, this is likely to adversely affect the Philippine corn growers particularly the small farmers who account for 75 per cent of the total corn harvest in the Philippines. Current efforts to develop high fructose syrup from corn and cassava (in Singapore and Thailand) through the application of biotechnology will affect the Philippine sugar exports. The large body of hired rural labour who are dependent on the sugar industry for their employment would be the worst affected. Similarly, the application of biotechnology to convert plant oils to produce structural lipids and tailored fats would affect the Philippine coconut oil exports. While coconut is the source of only 2 per cent of the world's oils and fats market, the Philippines alone supplies 80 per cent of the coconut. Decline in Philippine coconut export will directly affect the 15 million Filipinos dependent on the coconut industry for their livelihood, the majority of whom are poorer than the rest of the farming population.

-
1. These include a conceptual piece, an overview of plant-oils processing, a comparative study between Mexico and the United States on the impact of specific biotechnologies in the sugar and dairy industries; overall rural employment implications in China and Mexico; labour absorption in Malawi agriculture; an assessment of the contribution of biotechnology in combatting malnutrition in Nigeria; and diffusion studies for specific commercial and export crops in Kenya.

Biotechnology could improve the crop characteristics and food processing responding to certain health fads in the affluent societies. This would adversely affect some of the Philippine exports of certain fruits. The study points to the importance of creating local endogenous capacity to develop location-specific biotechnologies to counter the above adverse effects of biotechnologies acquired from the industrialised countries. The current national biotechnology programmes lack adequate domestic support, are too dependent on external assistance and lack the pro-poor focus and direction. However, the study points to the women scientists' dominant role in biotechnology generation where they predominate due to cultural reasons and because it was considered as a lowly paid basic science with previously limited linkages to industry.

Given the fact that the Philippines imports all of its chemical nitrogen fertilisers and that rice and sugar-cane account for over 78 per cent of the fertiliser consumption, increased use of locally-produced bio-fertilisers would save on foreign exchange and, being relatively cheaper, would be within the financial reach of most Filipino farmers. Farmers engaged in upland and lowland rice and corn cultivation have a range of bio-fertilisers to choose from. Their production is simple, labour-intensive and do not require sophisticated skills. Among the currently available bio-fertilisers, the nitrogen-fixing bacteria is identified as a least cost alternative although national production and distribution of inoculum needs to be improved. Policies affecting the relative prices of bio-fertilisers and chemical fertilisers would determine the extent to which the former is adopted.

In the Philippines, tissue culture is used to produce planting stock and test new lines of rice that are salt resistant and virus free, the use of which immediately increased yields. Tissue culture is also used in germplasm exchange and collection which prevents the spread of disease. Although virus-free root crop stocks are available at almost no cost, no conscious effort is made locally in directing technology development to different categories of farmers.

Bio-pesticides in the Philippines are environmentally valuable being non-pollutant compared to chemical pesticides. Essentially, bio-pesticides are micro-organisms and viruses that attack pests and pathogens. A fungal bio-pesticide (nematicide) for banana, potatoes and other crops developed locally is being manufactured in the private sector. Although the product is priced 30 per cent cheaper than its chemical counterpart for promotional purposes, cost reduction through competition is necessary to achieve lower prices reflecting actually reduced production costs.

Iftikhar Ahmed

Table of Contents

Page

PREFACE

INTRODUCTION	1
Purpose of the study	1
Philippine agriculture: Plans and programmes	1
BIOTECHNOLOGY DEVELOPMENTS ABROAD: A THREAT TO THE POOR	3
BIOTECHNOLOGY ACTIVITIES IN THE PHILIPPINES: IS THERE A PRO-POOR FOCUS?	6
LOCALLY-DEVELOPED BIOTECHNOLOGIES	10
Bio-fertilisers and labour intensity	10
Tissue-culture directed to small farmers	12
Bio-pesticides: Saving the environment and expanding market	15
Bio-fuels: Potentials	16
RESEARCH AND STRATEGY PLANNING	16
REFERENCES	18

BIOTECHNOLOGY TRENDS: A THREAT TO PHILIPPINE AGRICULTURE?

INTRODUCTION

One can argue that Philippine agriculture is more a victim rather than a beneficiary of technological breakthroughs and new scientific findings. Its once lucrative sugar industry has been brought to death's door by the advent of artificial sweeteners and the high fructose corn syrup. The world market for coconut products has not expanded as expected with population increases because of improvements in palm oil and soybean technologies. The finding that aflatoxin is carcinogenic and is contained in Philippine copra meal at levels above EEC standards could close the European market for this coconut product. On the other hand, unless government makes credit available, the modern rice and corn production technologies would remain beyond the reach of the majority of the Philippine farmers who are mostly poor and cash-starved.

The impact of biotechnology development is expected to be the greatest in agriculture.¹ There are several reviews that assess how these developments would affect Third World agriculture.^{2,3} Ahmed⁴ has argued that the bio-revolution has both pro-poor and anti-poor potentials, and the apparent trend is more anti-poor.

Purpose of the study

This study analyses trends in biotechnology research and development, both national and external in relation to Philippine agriculture. The following questions are being asked: Which of the current R&D affect the world market for Philippine major export crops, such as sugar, coconut and fruit crops? How do these research results affect the production of these crops and subsequently the small farmers? Are existing extension/technology transfer structures suitable for the dissemination of appropriate biotechnologies to small farmers? Are existing trends, programmes and structures in local R & D sufficient to propel Philippine agriculture into the fold of the bio-revolution?

Basically, the study examines the employment potential, distributional implications and nutritional dimension of the locally-developed biotechnologies. In this respect the study covers both new biotechnologies and the traditional ones for which the socioeconomic impact has not been adequately explored.

This study has five parts. The first part describes briefly Philippine agriculture and agricultural plans and programmes; the second discusses international biotechnological developments that would likely affect Philippine agriculture; the third part describes biotechnology activities in the Philippines; the fourth part discusses how some agricultural biotechnologies being developed in the country may affect the Filipino farmer; and the fifth discusses specific action the Philippines can take to benefit most from the developments in biotechnology.

Philippine agriculture: Plans and programmes

The Philippines has about 12 million hectares of arable land, more than nine million of which are devoted to rice, corn and coconut, while the rest to

rootcrops, vegetables, fruits and commercial crops. The principal export commodities used to be semi-processed or agricultural products derived from coconut and sugarcane which in recent years have been replaced by manufactured goods.

Agriculture has always been the biggest employer of labour. The National Census and Statistics Office data show that as of the first quarter of 1985, agriculture employed 9.293 million or 46.5 per cent of the total labour force, a slightly lower figure than the previous range of 50.4 per cent recorded from 1956-75. Women comprise more than 20 per cent of this labour force.

At the farm level, labour is supplied by the farmer-operator, his family, hired labour (seasonal or permanent) and exchange labour. The amount of labour supplied by the various groups appears to depend on the operator's access to capital to pay for labour,⁵ the crop being produced, the season of production, the technology of production, the culture of the community, and employment opportunities available especially to family members.^{6,7,8,9,10}

Farm families grow various crops and engage in both farm and non-farm income-generating activities. Despite these, poverty stalks the agricultural sector. The average farm family income per month of about \$63.57 (indicative figure) is below the poverty line of \$83.71 per month and well below the rural average family income of \$89.76 per month.¹¹ This has been attributed to low productivity¹² which in large part could be due to poor crop production. Yields per unit area are very low compared to those obtained in other countries or to expected yields. Poor yields are associated, among other things, with unfavourable climate, poor soil and poor technology.

The stated goal of the Department of Agriculture is to attain equity and economic recovery. The primary objective is to increase farm family income from the present indicative level of \$63.57 per month to at least \$95.24 per month by 1992. The other related objectives are to ensure food security, increase and stabilise earnings from agricultural exports and reduce dependence on products where there is a comparative advantage. The overall strategy is to provide a policy environment that will make farming profitable and improve the delivery of services to farmers. It has envisaged a private sector-led development process with bottom-up rather than top-down planning, with programmes that are area-specific and community-based rather than commodity-specific and national in scope, and that are income-oriented rather than production-oriented.

Problems have been identified for specific sectors and programmes are formulated for their solutions. The unequal distribution of land is recognised as a disincentive to farmers and landless workers, hence, assistance will be provided to beneficiaries of the Comprehensive Agrarian Reform Program. Programmes to assist the poorest of the poor, such as the upland farmers, cultural communities and subsistence fishermen, are being implemented. On the other hand, the rapid depletion of natural resources reduces the productivity and endangers the long-term sustainability of agriculture. Thereby, programmes that ensure ecological security as the foundation for food and income security, enforce regulations against illegal fishing, over-exploitation of marine resources and pollution of inland and marine waters are adopted.

Crop diversification is being promoted as a solution to the vulnerability of traditional exports (sugar, coffee and coconut) to world commodity markets, to the inadequate supply of some basic food items like beef and dairy and to our dependence on imported raw material inputs for agro-based industries.

The need to develop and disseminate technologies to improve agricultural production through research and extension is recognised. The following are the relevant issues: the inadequate funding support to agricultural research which is only 0.2 per cent of the agricultural gross value added in 1982; research priorities not aligned with farmer's needs; the fragmentation and duplication of research activities; and the slow pace of technology transfer due to weak linkage between research and extension. Several policies and programmes have also been formulated to promote/expand the market for agricultural products which includes trade liberalisation, market development and infrastructure support.

BIOTECHNOLOGY DEVELOPMENTS ABROAD: A THREAT TO THE POOR

This section presents and cites specific effects on the Philippine agriculture of general biotechnology trends, namely the increasing privatisation of biotechnology, the search for non-traditional uses of crops, the consequences of biotechnology developments arising from health fads, and new forms of production through biotechnology.

The increasing privatisation of biotechnology with the consequences of making knowledge and new technologies including new plant varieties and organisms in the control of the industrialised countries, has been widely recognised.¹³ Consequently, research is oriented to meet the needs of an affluent market such as the high value-low volume products in the pharmaceutical industry. Similarly, agricultural technology packages being developed by large multinational enterprises consist of improved seeds plus corresponding pesticides such as herbicide resistant corn. Moreover, the herbicide-resistant corn is not likely to immediately benefit the majority of corn farmers in the Philippines just as hybrid seeds had not. Corn hybrid seed adoption in the Philippines is a meagre 4 per cent¹⁴ despite several subsidised corn production programmes and the fact that several hybrids have been approved by the Philippine Seed Board since 1961. This low adoption rate could be attributed to the failure of corn production programmes to reach out and cater to the needs of the small corn farmers who produce 75 per cent of the total corn harvest in the country. Small corn farmers grow corn primarily for subsistence and prefer the open pollinated, white varieties which are more suitable for food and can produce the seeds for the next season's crop without substantial loss in yield. In the past, corn production programmes have been focused primarily on yellow (feed) hybrids, the seeds of which must be bought for every season's crop. Most likely, corn technology packages being developed will be geared towards the feed market since the market for feed corn is large anywhere in the world including the Philippines.

On the other hand, these technology packages represent another cost-reducing tool for the farmers of the United States and other industrialised countries, thereby increasing their competitive edge and reducing world corn prices. Without new and more appropriate technologies the Filipino corn farmer may not even be given a chance to compete at all even in his own market especially if corn import is liberalised.

Thus, it is necessary to maintain corn-breeding programmes in public institutions in developing countries like the Philippines. It is through these programmes that benefits in biotechnology can be achieved without depending on the genetically-manipulated parentals developed elsewhere. This brings to the fore an issue on the current trend of patenting such organisms. Although a patent does not keep a technology from being adopted, in this case, the question is whether it is fair for the Philippine public to pay for improvements made on one or two properties of the corn plant improved by

biotechnology when the public of industrialised countries did not pay for the domestication of corn and other crops originally obtained from the Third World now grown in the West.¹⁵

The continuing search for non-traditional uses of crops through genetic manipulation and bio-conversion would most likely affect the market of industrial crops such as sugar and coconut grown in the Philippines.

Cassava, a root crop that traditionally supplies starch for industrial and pharmaceutical use is being eyed as a source of high fructose syrup (HFS), a sweetener substitute for sugar. Thailand and Singapore are developing biotechnologies for the conversion of cassava starch into high fructose syrup,¹⁶ making cassava competitive with sugarcane. High fructose syrup from corn has eased the Philippine sugar out of a major portion of the United States sugar market. Undoubtedly, HFS from cassava would force the Philippine sugar to seek other markets as well. Otherwise, the industry may suffer another slump similar to that seen in 1984-86 when production, hectareage and employment dropped significantly. The result has been widespread poverty, malnutrition and growth of insurgency.¹⁷ The hardest hit was the rural labour market whose size is significant. It was created by, and is dependent on, the sugar industry.

The rapid pace of research on improving yields of various seed oil crops shall not only widen the price gap between coconut and other seed oils but could also create a glut in the seed oil market. This together with efforts to use enzymatic conversions of plant oils to produce structured lipids or tailored fats could in the future eventually ease the coconut oil out of the market. Only 2 per cent of the oils and fats market is supplied by coconut and the Philippines supplies about 80 per cent of that coconut.¹⁸

Structured lipids or tailored fats would allow the industry to produce oil formulations that simulate the desirable properties without the concomitant unwanted properties of various seed oils and natural fats. These simulated products could, therefore, be highly competitive with coconut and could displace it from its share of the seed oils market.

Fifteen million Filipinos are dependent on the coconut industry for livelihood and from the 1982-83 data, the majority are poorer than the rest of the farming sector.¹⁹ The industry has long been suffering from the unpredictability of the world market and a major technological advancement such as simulated oils and fats could restructure the market leaving a very low share for coconut oils. Unfortunately, the ability of coconut to compete is limited by its long gestation period so that interventions to improve farm productivity is not immediately realisable and, therefore, highly risky. Therefore, unless specific markets are found or created for coconut oil, its displacement by simulated oils could mean even poorer coconut farmers. And as always, the landless workers would be the worse-off members. On the other hand, bio-conversion of coconut could provide some solutions to expand both the local and foreign markets for the coconut. Moreover, small-scale bio-conversion systems can be designed to initiate the industrialisation of the coconut industry in the countryside.

Improvements on crop plant production and processing attainable through biotechnology tend to promote certain health fads which eventually affect the world market for specific commodities produced by the Philippines. The luxury of health fads is a privilege of industrialised countries which, unfortunately, adversely affects the world market of the Philippines' agricultural products. Looking into the developments of the United States sugar market, one can see that the shrinking of that market has been triggered by the low-calorie, sugar-free diet as a health fad. From current

developments, it appears that the Philippine coconut oil exports may suffer the same fate due to the cholesterol scare. High blood cholesterol has been associated with heart disease, and it is generally believed that saturated fats of coconut oil are cholesterol intermediates and, therefore, raise blood cholesterol. Health fads such as these have been reinforced by the ability of the technology sector to develop alternative products that cater to these fads and are made easily available. For example, the ready availability of artificial sweeteners and high fructose corn syrup reinforced the low-calorie, sugar-free products into a regular diet as a health fad thereby significantly reducing sugar demand.

Biotechnology gives a tremendous boost to the ability of the technology sector of industrialised countries to rapidly fill in needs created by health fads. A growing health fad in the United States and other industrialised countries is the preference for organically grown pesticide-free food. The exports of fruits from the Philippines - banana, pineapple and mango - are the second biggest users of pesticides imported into the Philippines (Table 1). Given the rapid pace with which disease and pest-resistant crops suitable to new environments could be developed through tissue culture and genetic engineering, there is a possibility that even the country's world fruit market could shrink or remain stagnant rather than expand. Apparently, it would not be sufficient for the Philippines to simply diversify the export crops as recommended by the Department of Agriculture but also to consider trends in consumer health fads that could affect the export market. On the other hand, the benefits of using either biological control or developing pest- and disease-resistant export crops may not only be derived from the savings in foreign exchange for the purchase of pesticides, and the cleaner environment that results due to less pesticidal use, but it may also ensure a steady, expanding market abroad.

Table 1

1984 Pesticide use by crops

Crop	Total pesticide (pesos)	%	% Insecticide	% Fungicide	% Herbicide
Rice	300,000	36.6	67.8	0.6	31.3
Banana	205,000	25.5	0.7	62.6	9.3
Vegetables	114,980	14.5	-	-	-
Mango	55,880	6.9	85.9	11.7	-
Corn	36,062	4.5	91.0	-	8.8
Tobacco	16,620	2.1	99.2	0.1	-
Cotton	7,013	0.9	95.8	2.2	-
Sugarcane	4,650	0.5	14.6	5.7	74.6
Pineapple	2,250	0.3	8.4	81.0	10.6
Coffee/Cacao	2,000	0.27	74.5	4.5	20.5

Note: Other pesticide items in the total but not itemised in the table include fishponds, fruits, snail chemicals, etc.

Source: Agricultural Pesticide Institute of the Philippines, 1984.

The new production systems of producing animal vaccines and hormones through fermentation by genetically-engineered cell systems could be beneficial and assist in attaining higher farm incomes. Since almost all veterinary products are imported into the country, the benefits of these new technologies in the form of cheaper and safer vaccines would affect producers as well as consumers. Lately, a multinational enterprise has introduced to the Philippines a human vaccine produced by a genetically-engineered micro-organism and priced less than half of its traditionally produced counterpart, thereby increasing its market towards a lower-income group. Similarly, cheaper and safer animal vaccines could become affordable by a greater number of livestock raisers, increasing production and supply and lowering prices of livestock products. On the other hand, the adoption of animal hormones to improve productivity is complicated by the need for technical assistance and efficient management abilities by the farmer-user. Given the earlier experience in the Philippines, it is most likely that only farmers near agricultural research and extension centres will benefit from this technology.

Of the new production systems that are currently being developed, that of the possible commercial production through fermentation of thaumatin, a plant protein that is a possible sweetener and sugar-substitute and whose gene has already been cloned into a microbe could further hurt the Philippine sugar industry. Thaumatin, aside from being 200 times sweeter than sugarcane, has the added advantage of being low-calorie and possibly highly nutritious.

BIOTECHNOLOGY ACTIVITIES IN THE PHILIPPINES: IS THERE A PRO-POOR FOCUS?

The above possible adverse impacts of biotechnology developed in the industrialised countries could be reduced if Third World countries develop an independent capacity in key areas of advanced biotechnologies and prevent the adoption of legislation permitting their patenting. The creation of centres such as the International Centre for Genetic Engineering and Biotechnology, as independent sources of knowledge for like-minded countries has also been seen as a countermeasure to the privatisation of biotechnology. In addition, biotechnology has been identified as a major area for support by quasi-public institutions and major international aid agencies. So, how does the Philippines fare in this respect? The following section presents the trends in biotechnology research and development in the Philippines and discusses the potential impact of beneficial biotechnologies being locally developed.

There is an awareness of the importance of biotechnology in the Philippines. Formally, the government extended support for a biotechnology research programme in December 1979, with the establishment of the National Institute of Biotechnology and Applied Microbiology (BIOTECH) within the University of the Philippines. The mandate of BIOTECH is to harness micro-organisms to transform renewable raw materials into food, fuel and fertiliser.¹⁹ Prior to BIOTECH there have been small biotechnology projects conducted by agencies within the Agricultural Research Network coordinated by the Philippine Council for Agriculture and Resources Research and Development, but these have not been identified separately as such but rather as components of commodity-oriented programmes in agriculture. Consequently, the support for biotechnology research programmes for application to rural areas has not been consistent (Table 2). This seems to reflect the general lack of government commitment to research and subsequently the dependence of the research sector on external grants. Without the external grants, there has actually been a continuing reduction in support for biotechnology research (Table 3). More disturbing is the consistent decrease in allocations for maintenance and operating expenses.

Table 2

Expenditure for biotechnology research with agricultural applications
(in million pesos)

	1982	1984	1985	1986
Total expenditure for agricultural research	76.299	104.338	120.552	108.981
At constant 1978 prices	44.052	36.431	34.189	30.476
Expenditure for biotech projects	10.210	8.343	29.324	12.496
At constant 1978 prices	5.895	2.913	8.317	3.494
As percentage of total expenditure for agricultural research	13.4%	8.0%	24.3%	11.5%

Source: Pooled from data obtained from BIOTECH, UPLB Office of the Director and from PCARRD, DOST Office of the Executive Director.

Table 3

Budgetary expenditure for research at the National Institute of Biotechnology and Applied Microbiology
(in million pesos)

	1980	1981	1982	1983	1984	1985	1986	1987
Total	8.021	5.811	10.210	6.006	8.343	29.324	12.496	12.783
Grants	-	-	2.627	-	3.27	24.902	7.119	6.581
Core	8.021	5.811	7.583	6.006	5.073	4.422	5.377	6.202
Personnel	1.287	3.178	3.257	3.227	2.243	3.556	4.620	5.187
M O E	4.118	2.633	2.166	2.180	1.731	.866	.757	1.015
Equipment	2.616	0	2.160	.599	0	0	0	0

Source: BIOTECH, UPLB, Office of the Director.

Nevertheless, the scientific community has maintained a rural sector-oriented programme. BIOTECH has adopted four inter-disciplinary research programmes, namely: bio-fuels from agricultural crops and residues,

nitrogen fixation and enhancement of soil nutrient availability, establishment and improvement of traditional food fermentation processes, and special projects on veterinary antibiotics, plant diagnostic and plant cell cultures for secondary metabolite production. For the years 1980-84, BIOTECH spent 26 per cent of its direct costs of research for the bio-fuels programme, 32 per cent on nitrogen fixation programme, 19 per cent on the food programme and 23 per cent for its special projects. On the other hand, the Agricultural Research Network has been consistently active in tissue-cultured seeds and bio-fertilisers (Table 4).

Table 4

Relative expenditures in various research areas in biotechnology
within the Agricultural Research Network
 (in % of total expenditure for agricultural biotechnology)

Research area	1981	1982	1984	1985	1986	1987
Tissue cultured seeds	23.3	21.9	21.9	20.2	34.8	41.0
Bio-fertilisers	22.6	11.0	21.6	28.8	44.8	33.5
Microbial pesticides	5.1	19.9	6.3	6.1	5.4	-
SCP	32.0	30.7	31.6	19.4	-	2.9
Bio-fuels (alcohol and biogas)	6.9	12.8	0.2	13.2	3.7	3.4
Bio-conversion for food beverages (including mushrooms)	-	-	5.1	9.8	4.7	10.9
Plant growth regulators	6.9	-	0.9	-	-	1.0
Diagnostics (plant)	-	-	12.4	2.4	6.6	8.3
Animal reproduction (superovulation)	3.1	3.6	-	-	-	-

Source: Calculated from data supplied by the PCARRD, Office of the Director.

The support for biotechnology is expected to increase with the operationalisation of two government agencies within the Department of Science and Technology, viz. the Philippine Council of Advanced Science and Technology Research and Development (PCASTRD) and the Advanced Science and Technology Institute (ASTI) both having mandates to promote biotechnology research and development. In May 1988, the PCASTRD included agricultural biotechnology as one of its four priority sectoral concerns and identified genetically-engineered planting stocks as a priority commodity concern for research. The long-term approach of producing restriction fragment length polymorphisms (rflp) maps for major crop plants is considered a top priority.

There is private sector involvement in biotechnology. One seed company in the Philippines, a subsidiary of a multinational enterprise has started research on corn tissue culture. A private company teamed up with the University of the Philippines at Los Banos for the testing and commercialisation of Paecilomyces lilacinus, a fungus against root nematodes attacking banana, potato and other crops. Negotiations are currently underway for a joint sugarcane biotechnology programme between scientists of the University of the Philippines, sugar millers, sugar planters and the Sugar Regulatory Administration.

The issue of bio-safety has been raised and pending before the Philippine Senate is a bill creating a national Biosafety Board for the regulation of biotechnology projects. Parallel to the Senate move is the creation of an interagency committee on bio-safety created by the heads of the Department of Agriculture, the University of the Philippines at Los Banos and the International Rice Research Institute. Guidelines on the conduct of biotechnology projects (research and non-research) have been formulated by this committee.

Although the issue on bio-safety has been initially raised from circumstances arising from laxity of quarantine procedures and unfounded fears of biotech projects, the concern of others could be real. There may be a need for such a law considering the experience of the Philippines as the dumping grounds of unwanted technologies and products from developed countries. The possible use of the Philippines as experimental ground for biotech products and processes cannot also be discounted. Due to the lack of experience in this field, there is no knowledge of the risks involved in biotech products. Understandably, the PCASTRD has included bio-safety as a researchable area.

The research techniques currently employed in the development of various biotechnologies has not quite reached the level of sophistication one automatically associates with genetic manipulations. Most of the work being done with N-fixation is basic microbiology and field testing, biogas concerns technofeasibility, alcohol research involves process development, bio-pesticides constitutes basic microbiology and efficacy testing and tissue-culture is used for micropropagation.

Of these biotechnologies, tissue cultured seeds appear to be moving forward technically, in that 13 out of 60 studies reported are now concerned with cell and protoplast culture and in vitro selection. Of about 100 research projects examined, only two projects, one on coconut disease and another on cellulose degradation, are working at the DNA level and four projects use cell fusion as a technique for improving cellulose degradation, for increasing alcohol yields, for improving animal vaccine production and/or producing monoclonal antibodies for plant viral diagnosis. This state reflects both the limited number of personnel trained in the new technology and the lack of funds to support new projects.

Interestingly, work on all of these advanced projects is carried out primarily by women. And, on the whole, based on membership of professional societies, the field is dominated by women. The Philippine Society for Microbiology consists of 80 per cent female and 20 per cent male members the Cell/Molecular Biology and Biotechnology Society is 74 per cent female and 26 per cent male, and the Philippine Association for Plant Tissue Culture is 85 per cent female and 15 per cent male. The predominance of women in the field could be related to the character traits of the Filipino that appears to be gender-associated. Cell and molecular biology research requires patience and perseverance, traits often associated with Filipino females rather than the Filipino male. Alternatively, the reason could be economic. That is, scientific research in the biotechnology field in the Philippines does not pay

well, hence the Filipino male who is expected to be the family provider shies away from a scientific career in this field.

LOCALLY-DEVELOPED BIOTECHNOLOGIES

Local research resources have been expended mainly on the development of four biotechnologies, namely, bio-fertilisers, bio-fuels, bio-pesticides and tissue-cultured seeds. Each of these is examined more closely below to assess possible impact particularly on the small farmers.

Bio-fertilisers and labour intensity

One of the major research programmes receiving widespread international support in biotechnology is the utilisation of nitrogen-fixation as an alternative to the intensive use of chemical nitrogen fertilisers. There are two general biological systems that can be harnessed in nitrogen-fixation, the symbiotic and the non-symbiotic systems. The symbiotic system is composed of a specific plant species and a bacteria which together fix atmospheric nitrogen to a form assimilable and utilisable by the plant. In using this system as bio-fertiliser, the plant component is either used as green manure, as part of the compost material, or if the crop plant is leguminous, an improved N-fixing bacteria is inoculated with that plant. Examples of a symbiotic system are the Azolla-Anabaena and legume-Rhizobium complexes. Nonsymbiotic or free-living systems consist of nitrogen-fixing organisms that form loose associations with crop plants and are found within the habitat or within the root zone of a crop plant where the organisms fix nitrogen and excrete nitrogenous compounds utilisable by the plant. Examples of such organisms include the blue-green algae and rhizosphere bacteria such as Azospirillum, Clostridium and others.

There is a strong particular interest in harnessing biological nitrogen fixation in producing bio-fertilisers in the Philippines. One reason is that the Philippines imports all of its chemical N-fertiliser and additional foreign exchange expenditure is required to fully supply the needs for expanding agricultural production and to meet the additional costs resulting from the projected increase in fertiliser prices (Table 5). Moreover, increased use of fertiliser is needed because crop production depletes the soil of nutrients (Table 6). More importantly, bio-fertilisers are perceived to be cheaper and within the financial reach of most Filipino farmers who cannot maintain their level of fertiliser requirements due to financial constraints.²⁰

Systems recommended and studied as bio-fertilisers include the Azolla-Anabaena, crop legume-Rhizobia, Sesbania-Rhizobia and Leucaena-Rhizobia as green manures or compost components, compost, blue-green algae and nonsymbiotic nitrogen-fixing bacteria. Recipient crops being studied are crop legumes, mainly peanut, mungbean and soybean, rice, corn and sugarcane. Rice and sugarcane production consume 78.4 per cent of the total fertilisers traded in the country. Corn is the most extensively grown crop by small farmers in the nutrient-poor soils of the uplands and yet, fertiliser application is not a common practice.

A rice, corn or sugarcane farmer has several bio-fertilisers to choose from. An upland rice or corn farmer has a choice among a legume (Leucaena) green manure, compost and a nonsymbiotic N-fixing bacteria. A lowland rice farmer has the Azolla-Anabaena system, Leucaena or Sesbania green manure, a free-living N-fixing and blue-green algae to choose from. All these bio-fertilisers are simple to produce and do not require sophisticated skills

Table 5

Actual and projected prices for fertilisers
(FOB prices at constant 1986 dollars)

		Urea	Diammonium phosphates	\$/ton Triple superphosphate	Potash
		(NW Europe)	(Florida)	(Florida)	(Vancouver)
<hr/>					
Actual:					
1972-1976 Crisis					
	1972	141	216	160	79
	1973	212	266	223	95
	1974	651	686	626	125
	1975	373	458	381	153
	1976	201	215	163	99
	1986	107	160	120	73
	1987	112	150	126	68
Forecasts:					
Annual					
	1988	130	185	135	70
	1989	140	200	150	70
	1990	180	205	155	70
	1991	220	225	170	70
	1992	280	265	210	75
	1993	260	325	260	85
	1994	230	265	210	90
Trend					
		220	250	195	125

Source: Fertiliser and Pesticide Authority, March, 1988.

Table 6

Nutrient removal by crops

Crop	Yield level (Kg/ha)	Nutrient removal Kg/Ha		
		N	P	K
Rice	4,000 (grain)	90	35	110
Corn	4,500 (grain)	110	45	155
Sugarcane	90,000 (canes)	120	75	250
Coconut	100 (trees)	53	50	93

Source: Fertiliser and Pesticide Authority, 1988.

and equipment. However, they do require different amounts of resources. Table 7 compares the resource requirements of producing and using four bio-fertilisers equivalent to 30kgs N; Azolla-Anabaena as in situ grown green manure, Leucaena as cut and carry green manure, and nonsymbiotic N-fixing bacteria. The N-fixing bacteria requires the least of the farmer's resources provided that the inoculum is produced and made available to the farmer at the current cost of Rhizobium inoculants. A good measure of government investment is required in setting up a network of fermentation plants to provide this service. This also means that the system should improve upon that presently used for Rhizobium inoculum production and distribution which is not even used in more than 10 per cent of the areas planted to legumes. It should be noted that this technology addresses the most disadvantaged farmer groups, the upland rice and corn farmers. The technology also addresses sugarcane farming, the most intensive user per unit area of N-fertiliser based on PHILSUCOM recommendation of 200-100-300 NPK per hectare.

The bio-fertilisers are labour-intensive especially leucaena cut and carry green manuring and composting. Although it is often believed that labour-intensive technologies are economically desirable in the rural areas to absorb the increases in rural labour supply, those technologies that support production of price-controlled commodities such as rice would perpetuate rural poverty and widen the gap between the landless poor and the rest of the rural sector. This would be true in areas where labour supply is high and "gama" is practised. "Gama" is the practice of non-payment in cash of labour supplied during the growing phase of crop production. Instead, all the hired labourer gets is a free meal and an assurance that he/she will be part of the harvesting and threshing team.²¹ "Gama" therefore is exploitative of landless workers since essentially the labour rendered before harvest is either free or loaned out to a resource-richer member of the sector. Labour-intensive technologies tend to reinforce "gama" which is practised in some regions of the country. On the other hand, if sufficient family labour exists and no alternative non-farm income generating activity is available, the use of compost, Azolla and Leucaena would make economic sense only when the cost of the compost inoculum is lowered significantly below the price of the substituted N-fertiliser. The Azolla requires less or no pesticide and Leucaena leaves cannot be sold as feed component and its production does not require pesticides. On the other hand, currently research is underway on a system of green manuring using Sesbania with much reduced labour requirements.

Tissue-culture directed to small farmers

Traditionally, improvements of biological systems have been attained from gradual refinements of the systems' genetic make-up. In crops, the breeding for high-yielding, disease-resistant plants is a complex and time-consuming process. Individuals with desirable traits must be selected from a thousand population or so, hybrids are made and grown, promising individuals are selected and grown further for testing to find the right mix of properties. Further screening is done to see how stable this mix is, then another series of crosses may again be made and further screening. This process in annuals can easily take a decade or so.

The new biotechnology has brought down some of the initial extensive and time-consuming selection trials at the laboratory level where units for selection are not whole plants but cells and bits of tissues which, when selected, can be regenerated into whole plants. This technique of cell/tissue culture has been successfully used in rice to produce within four years, varieties that have wide adaptability and are high-yielding (7.5 MT/ha),

Table 7

Main inputs needed to produce biofertilizers equivalent to 30kgs N/ha current price
(market price @ \$0.09/kg urea)

COMPOST ¹				AZOLLA ²			
	Quantity	Unit cost		Total cost	Quantity	Unit cost	
		Actual	Breakeven			Actual	Breakeven
Labour	64 manhours	\$0.28/manhour	\$0.09/manhour	\$17.92	40/manhours	\$0.28/manhour	\$0.15/manhour
Materials							
Seeds/Inoculum required	32kgs	\$0.48/kg	-	\$15.36	-	-	-
Fertiliser	0	-	-	-	12kgs P	\$0.16/kg	-
Pesticide	0	-	-	-	.015-2kgs a.i.	\$37.00/kg	-
							\$0.56-\$74.00
Opportunity cost	1,400kgs Leucaena leaves	\$0.01/kg	-	\$14.00	-	-	-
	1,400kgs Chicken manure	\$0.02/kg	-	\$28.00	-	-	-
Area taken out of production to produce biofertiliser	0	-	-	-	-	0.004-0.1 ha (for inoculum production)	-
Time required to produce effective biofertiliser at the farmer's level	28-30 days	-	-	-	-	20 days	-

Table 7 continued

LEUCAENA ³					NON-SYMBIOTIC N-FIXING BACTERIA ⁴		
	Quantity	Unit cost		Total cost	Quantity	Unit cost	Total cost
		Actual	Break-even				
Labour	120 manhours	\$0.28/manhour	\$0.05/manhour	\$33.60	2 manhours	\$0.28/manhour	\$0.56
Materials							
Seeds/Inoculum required	0.875kg	\$0.95kg	-	\$0.83	1 packet	\$0.48	\$0.48
Fertiliser	6.25kgs	\$0.16kg	-	\$1.00	-	-	-
Pesticide	-	-	-	-	-	-	-
Opportunity cost	1,500kgs dried Leucaena	\$0.10/kg	-	\$150.00	-	-	-
Area taken out of production to produce biofertiliser	0.5 ha	-	-	-	0	-	-
Time required to produce effective biofertiliser at the farmer's level	90 days	-	-	-	N.A.	-	-

1. Calculated based on data and recommendations given in: PCARRD, 1987. Make composting easy with Trichoderma, Technology, 9:(5). PCARRD, Los Banos, Laguna, Philippines, p. 16.
2. Recalculated from Kikuchi, M., I. Watanabe and L.D. Haws, 1982. Economic evaluation of Azolla use in rice production, in Proceedings of the International Conference on organic matter and rice, 27 Sept - 1 October 1982. IRRI, Manila, Philippines.
3. Calculated based on data and recommendations given in PCARRD, 1980. The Philippines recommends for Ipil-ipil. PCARRD, Laguna, Philippines.
4. Based on inputs for Rhizobium inoculation.

resistant to bacterial blight and tolerant to salt, which are now planted extensively in China.²²

However, the new techniques have expanded and made more specific processes that create new genetic capabilities and variations. The technique of genetic engineering has allowed for the introduction of specific and new property or capability in plants. For example, the ability to degrade specific herbicides, a property discovered in micro-organisms has now been transferred and expressed in several plants. Somaclonal variation, a phenomenon observed in plant tissue cultures that produces genetic variation, has produced new lines of rice that are salt resistant and are now being tested in the country. In addition, tissue culture has been used to produce virus-free planting stock, the use of which immediately increased yields and in germplasm exchange and collection which prevent the spread of diseases.

No conscious effort is locally made in directing technology development to different types of farmers. Virus-free root crop stocks are available at almost no cost. But embryo-rescued mutant coconut (macapuno) planting stock is too expensive (\$23.80/plant) that mostly plant collectors are able to buy.

The International Rice Research Institute has intensive work on rice biotechnology supported by the Rockefeller Foundation and is directed towards rice farmers missed out by the Green Revolution. However, only a few of the outcomes of this technology development are applicable to Philippine conditions. This is also true of the Tissue Culture for Crops Program of the Colorado State University and supported by the United States Agency for International Development. The latter programme, however, supports an upland rice and corn improvement through a tissue culture project, being carried out at the Visayas College of Agriculture in Central Philippines.

What this indicates is that international research programmes should not be looked upon as sufficient to generate location-specific biotechnologies and that local capabilities need to be developed to fully utilise technical assistance and training provided by these international programmes.

Bio-pesticides: Saving the environment and expanding market

Bio-pesticides are micro-organisms and viruses that attack insect pests and pathogens. The most widely known is the bacterium, Bacillus thuringiensis which is effective against lepidopterous insects. Aside from bacteria, fungi and viruses are being studied as bio-pesticides. Although helpful to farmers and to the public in general because of their environmental value as non-pollutant compared to chemical pesticides, bio-pesticides like chemical pesticides, may differentiate between poor and rich farmers. Since the trend is to develop a capital-intensive production technology, the production, distribution and sale will be in the hands of the private sector. The University of the Philippines has recently awarded the production of a fungal nematocide for banana, potatoes and other crops to a private company. Although this nematocide is priced at least 30 per cent lower on an area need basis than its chemical counterpart, this pricing scheme is evidently directed not towards market expansion but rather more towards product promotion. The price could have been much lower and affordable to more farmers had the pricing been based on production cost. Thus, unless more production firms enter to ensure competition, improve efficiency of production and bring down prices, the real benefits of such locally-developed technology will not spread to a greater number of farmer-users.

Bio-fuels: Potentials

Bio-fuels in the present Philippine context are biogas, the flammable, odourless gas produced by anaerobic micro-organisms actively growing on agricultural or industrial wastes, and fuel alcohol, anhydrous ethanol derived from the fermentation by yeast of sugar-rich materials. The technology development for biogas has been directed towards the richer farmers because of the capital outlay needed to make the system operational. The technology is subject to economies of scale and although efforts have been made to lower the capital cost, the smallest system is still too expensive at \$286-332 per unit, not including the investment cost of rearing pigs to supply the raw materials. Presently, large industrial plants and livestock farms are more interested in biogas systems for their waste treatment value, and with their fuel value as an added bonus. The fuel value, however, is extremely attractive with the investment for a system paying off about two years after the start of operation and continuously saving on fuel/electricity costs thereafter. Maya farms, a 6,000 head livestock farm and food-processing complex rely completely on biogas for its fuel needs, saving the company an equivalent value of about \$38,000 monthly on electricity costs.

The greater effect of biogas technology on agricultural production is the concomitant production of sludge and water effluents which are major components of commercial formulations of organic fertiliser. More firms adopting the biogas technology means more organic fertiliser and hence, hopefully lower prices which are more affordable to more farmers.

Alcohol for fuel has been intended to buffer the country from increases in fossil fuel prices and to develop an alternative local market for sugar. The alcohol for fuel programme has not taken off the ground since economic conditions have so far been unfavourable. Habito²³ argues that presently fuel alcohol production does not make economic sense because it spends foreign exchange more than the price of the equivalent amount of gasoline saved.

RESEARCH STRATEGY AND PLANNING

From the foregoing discussion, it is apparent that the current trend in biotechnology development abroad could adversely affect Philippine agricultural development and that the national efforts of harnessing new knowledge for agricultural technology development lacks adequate support, direction and focus.

Sugar may face a stiffer competition from new sweeteners such as thaumatin or from a cheaper HFS and, similarly, coconut from simulated oils and fats and fruits, from pesticide-free fruits. The poor corn farmers may even lose their chance to sell in the local feed market with stiffer competition from imported biotechnology-based corn.

Although biotechnology R & D activities have been launched in the Philippines and such activities are directed to existing problems, very few are directed towards the more pressing problems of survival and maintenance of the comparative advantage in the Philippines' major crops. Furthermore, the national capability to use the revolutionary techniques of cell and molecular biology is very limited, and such limited capability is spread out thinly to various unrelated problems.

Since it is an established norm that scientific research receives insufficient funds, appropriate and timely technological interventions can only be made through careful planning and through evaluation of the

capabilities of and resources necessary to develop appropriate biotechnologies. An overall development strategy that specifies points for technological intervention should be designed for agriculture that could affect at least 70-80 per cent of the agricultural sector with the overall objective of increasing incomes. Understandably, points of technological interventions should be the areas of research where the pay-off for research investment should be the greatest.

Timely and rapid development of appropriate technologies are likely to be achieved by concentrating the nation's limited resources, including manpower, on the development of a few such identified points of technological interventions within specific periods of time.

The biggest obstacle to the development of local technologies is the pervasive colonial mentality, expressed as the incapacity of the public to believe that important advances could come from their own Filipino scientists. This has resulted in the poor support for research and the preference for imported, turn-key technologies. Unfortunately, biotechnology is location-specific and requires local capability for development. Thus, it is essential that the Philippine public perception towards its own scientific sector changes. And at the same time, this scientific sector must also realise that biotechnology is a strategic technology, central to the struggle to retain or regain international competitiveness, and certain to have a major economic impact.²⁴

With the rapid pace of biotechnological developments, Philippine agriculture needs to adopt a growth plan that must take into account these developments and adjust its strategies accordingly. Undoubtedly, biotechnology must be part of these strategies as it is a major tool that can provide that quantum leap from scarcity and vulnerability to abundance and stability.

REFERENCES

1. UNCSTD (1984): "Tissue culture technology and development", ATAS Bulletin (New York, UNCSTD), November.
2. Buttel, F.H., B. Kenny and J. Kloppenburg, Jr. (1985): "The IARCs and the development and application of biotechnologies in development and application of biotechnologies in developing countries", in Biotechnology in International Agricultural Research Proceedings of the Inter-Center Seminar on International Agricultural Research Centers (IARCs) and Biotechnology, International Rice Research Institute, Manila, Philippines.
3. Van den Doel, K. and G. Junne (1986): "Product substitution through biotechnology: Impact on the Third World", Trends in Biotechnology, 4:88-90.
4. Ahmed, I. (1988): "The bio-revolution in agriculture: Key to poverty alleviation in the Third World?", International Labour Review, 127:53-72.
5. Castillo, G.T. (1978): "Philippine rural problems in perspective", International Development Research Centre, Ottawa, Canada.
6. Castillo, G.T. (19__): "Filipino in rice farming systems: Some empirical evidence", paper presented at the Women in Rice Farming Systems Workshop, International Rice Research Institute, Manila, Philippines.
7. Kenmore, Z.F. (1988): "Women, households and farmings systems in an upland area: Misamis Oriental, Philippines". Paper presented at the Women in Rice Farming Systems Workshop, International Rice Research Institute, Manila, Philippines.
8. Illo, J.F.I. and C.C. Veneracion (1988): "Women and men in rainfed farming systems". Paper presented at the Women in Rice Farming Systems Workshop, International Rice Research Institute, Manila, Philippines.
9. Rivera, F.T. and V.C. Vilorio (1987): "Participation of rural women and children in handwatering agriculture for crop diversification: The case of Luzon, Philippines", in Proceedings of the Third Annual Scientific Meeting, Federation of Crop Science Societies of the Philippines, U.P. Los Banos College, Laguna, Philippines.
10. Alcober, D.L., G.C. Buenavista and F.T. Belina (1988): "Incorporating women's concerns in the forming systems development project. Eastern Visayas. Paper presented at the Workshop on Women in Rice Farming Systems, 3-11 May. International Rice Research Institute, Manila, Philippines.
11. Department of Agriculture, Government of the Philippines (1987): "Policies, priorities and medium-term program of action". Unpublished, Quezon City, Philippines.
12. Agricultural Policy and Strategy Team (1986): "Rural poverty and poverty programs in the Philippines", in Agenda for action for the Philippine Rural Sector, University of the Philippines at Los Banos, College, Laguna.
13. Dembo, D., C. Dias and W. Morehouse (1984): "Impact on social relationships: The risk of the privatisation of technology", ATAS Bulletin I Tissue Culture, New York UNCSTD.

14. Mendoza, E.M.T. (1985): "An assessment of the contribution of national plant breeding programs to nutrition in the Philippines", paper presented at the Nutrition and Welfare Workshop", University of the Philippines at Los Banos, Working Paper No. 85-1733, October.
15. Sasson, A. (1987): "A challenge for the developing world", UNESCO Courrier, March.
16. Report of the Asean Experts on Technology, Melbourne, Australia, 25-30 August.
17. Gonzaga, V.L. (1987): "Crisis and challenge in negros occidental: A study of the sugarcane workers differential perceptions and responses", Social Research Center, La Salle Bacolod City, Philippines, December.
18. Sangalang, J. (1985): "The coconut replanting program", paper presented at the Rice Economy and Agricultural Trade Policy Workshop", CPDS, U.P. Los Banos, Philippines, 3-4 May.
19. Padolina, W. (1985) "Brief history of BIOTECH's operations 1980-1984", ULPB BIOTECH College, Laguna.
20. PCARRD (1983): "Philippine recommendations for fertiliser usage", PCARRD Technical Bulletin No. 52, Los Banos, Laguna, p. 103.
21. Aragon, C., V. Cordova and E. Gasem (1985): Rural employment in the Philippine rice sector.
22. Hu Han (1985): "Use of haploids in crop improvement", in Biotechnology in international agricultural research. Proceedings of the Inter Center Seminar on International Agricultural Research Centers (IARCs) and Biotechnology, 23-27 April 1984, IRRI, Manila.
23. Habito, C.E. (1988): "Socioeconomic evaluation of energy development projects", paper presented at the PCIERD Symposium on Energy Technologies, Makati Sports Club, 25-26 April.
24. Yoxen, E. (1987): "The impact of biotechnology", Trends in Biotechnology, 5:160-163.

WORLD EMPLOYMENT PROGRAMME

TECHNOLOGY AND EMPLOYMENT PROGRAMME

Working Papers

WP. 1	Employment and coffee production techniques	L.D. Smith and C.F. Brown February 1974
WP. 2	The choice of technique and employment in the textile industry	Howard Pack March 1974
WP. 3	Thai workers in heavy road construction activities. An ergonomic pilot study	R. Eriksonn A. Yllo N. Lundgren April 1974
WP. 4	Mass production of dwellings in Colombia: A case study	P. Strassmann April 1974
WP. 5	Capital-labour substitution possibilities: A review of empirical research	J. Gaude May 1974
WP. 6	Indirect employment effects of investment in industry	J. Krishnamurty
WP. 7	Industrialised systems building for developing countries: A discouraging prognosis	P. Strassmann July 1974
WP. 8	Concept and measurement of labour-intensity	A.S. Bhalla August 1974
WP. 9	Conventional technology, construction wages and employment	P. Strassmann August 1974
WP. 10	"Men and machines": A Philippines case study of labour-capital substitution in road construction	Deepak Lal September 1974
WP. 11	Effect of farmers' education on agricultural productivity and employment: A case study of Punjab and Haryana States of India (1960-1972)	D.P. Chaudhri October 1974
WP. 12	The green revolution, mechanisation and employment	Iftikhar Ahmed January 1975
WP. 13	The role of design in the choice of road construction techniques	G.A. Edmonds February 1975
WP. 14	Selection of road projects and the identification of the appropriate road construction technology : General considerations	Moise Allal February 1975
WP. 15	A framework for data collection on road construction	G.A. Edmonds March 1975

WP. 16	The Green Revolution in Bangladesh: Adoption, diffusion and distributional question	Iftikhar Ahmed June 1975
WP. 17	A planning model incorporating technological choices and non-homogeneous supplies of labour	J. Gaude June 1975
WP. 18	Organisation, consumer time and technology in services	A.S. Bhalla and J. Gaude July 1975
WP. 19	Low-cost technology, cost of labour management and industrialisation	A.S. Bhalla July 1975
WP. 20	Can-making techniques in Kenya, Tanzania and Thailand	R.M. Bell, C.M. Cooper, P. Kaplinsky October 1975
WP. 21	A case study of alternative techniques for open-top can manufacture in Thailand	R.M. Bell, C.M. Cooper, P. Kaplinsky
WP. 22	The effect on employment of change in technology in tea and coffee plantations in India. Part A - Coffee	I.Z. Bhatt December 1975
WP. 23	The effect on employment of change in technology in tea and coffee plantations in India. Part B - Tea	I.Z. Bhatt December 1975
WP. 24	Technologie et emploi dans le secteur de la construction en Tunisie	P. Perchiou and R. Lakhous December 1975
WP. 25	Technological development and role of R and D institutes in developing countries - The Korean case	Nam Kee Lee December 1975
WP. 26	The role of services in increasing capacity utilisation: The case of Tanzanian manufacturing industry	S.M. Wangwe December 1975
WP. 27	Local capability and preparedness for appropriate technology transfer to developing countries	M.M. Suri December 1975
WP. 28	Agricultural mechanisation in Iran	V.F. Nowshirvani March 1976
WP. 29	Labour-intensity construction of irrigation works	M.I. Hussain August 1976
WP. 30	Structure of the agricultural machinery and implements in industry to Iran	V.F. Nowshirvani March 1977
WP. 31	Employment and technology transfer and adaptation: The case of the agricultural machinery industry in Iran	V.F. Nowshirvani March 1977
WP. 32	Technology, products and income distribution: A conceptualisation and application to sugar processing in India	J. James November 1977

WP. 33	Study of small contractors in Kenya	J. Capt and G.A. Edmonds December 1977
WP. 34	Technological linkages between formal and informal sectors of manufacturing industries	Susumu Watanabe March 1978
WP. 35	Technology diffusion from the formal to the informal sector: The case of the auto-repair industry in Ghana	A.N. Hakam July 1978
WP. 36	Technologies appropriate for a basic needs strategy	A.S. Bhalla August 1978
WP. 37	National appropriate technology groups and institutions: a preliminary assessment	A.K.N. Reddy September 1978
WP. 38	Cambio tecnologico y empleo en la produccion agroindustrial de azucar en Tucuman	Manuel Mora Y Araiyo y Dora Orlandsky October 1978
WP. 39	Technological change and the condition of rural women: a preliminary assessment	Iftikhar Ahmed October 1978
WP. 40	Equipment for labour-based road construction	J. Howe and I. Barwell November 1978
WP. 41	Scope for application and upgrading of indigenous technology - the case of irrigation works	M.I. Hussain November 1978
WP. 42	Choice of manufacturing technology in the leather shoe and brick industries in Malaysia	Chee Peng Lim December 1978
WP. 43	The effect of higher oil prices on technology and employment in Pakistan	M. Ahmed January 1979
WP. 44	The technological and employment implications of higher oil prices: a case study of Sri Lanka	Marga Institute, Sri Lanka January 1979
WP. 45	The changing patterns of intersectoral technological linkages in the rural machinery industry in China	Jon Sigurdson January 1979
WP. 46	Technological change and rural women - a conceptual analysis	Amit Bhaduri January 1979
WP. 47	Technical cooperation between large and small firms in the Filipino automobile industry	Susumu Watanabe March 1979
WP. 48	(with Jobs and Skills Programme for Africa) Small contractors: untapped potential or economic impediment? Some observations on the construction industry in Cameroon, Niger and Sierra Leone	Bernd Balkenhol April 1979
WP. 49	On the production of appropriate technology	Henry J. Bruton June 1979

WP. 50	Impacts of higher oil prices on India	Ashok V. Desai September 1979
WP. 51	The generation and dissemination of appropriate technologies in developing countries: a methodological approach	Amilcar O. Herrera October 1979
WP. 52	Some economic implications of higher oil prices: the case of Bangladesh	Rizwanul Islam November 1979
WP. 53	Organising for technology appropriation: an approach to appropriate technology implementation	Geoff Lamb December 1979
WP. 54	Inter-sectoral linkages in the metal engineering industry in Kanput, India	T.S. Papola R.S. Mathur December 1979
WP. 55	Technological linkages in the Mexican garment industry	Alfonso Mercado January 1980
WP. 56	Consumer, income distribution and appropriate technology: the case of bicycle manufacture in Malaysia	Fong Chan Onn March 1980
WP. 57	Energy options for low-lift irrigation pumps in developing countries - the case of Bangladesh and Egypt	David Birch J.R. Pydzewski April 1980
WP. 58	Technological linkages in the Egyptian cotton weaving industry	Hatem El Karan-shawy Mohamed Sakr April 1980
WP. 59	Product choice and poverty: a study of the inefficiency of low-income consumption and distributional impact of product changes	J. James May 1980
WP. 60	Technological choice, employment generation, income distribution and consumer demand: the case of furniture making in Kenya	W.J. House May 1980
WP. 61	Technology and rural women in Africa	Marilyn Carr July 1980
WP. 62	Some technological issues of informal sector industries in Khartoum	Ali Ahmed Suliman July 1980
WP. 63	Labour-based technology for large irrigation works: problems and prospects	Asit K. Biswas August 1980
WP. 64	Farm equipment innovations, agricultural growth and employment in Zambia	B.H. Kinsey August 1980
WP. 65	Technology, employment and basic needs in leather industries in developing countries	Arie Kuyvenhoven August 1980
WP. 66	Institutional factors and government policies for appropriate technologies in South-East Asia	Shinichi Ichimura September 1980

WP. 67	Institutional factors affecting the generation and diffusion of agricultural technology: Issues, concepts and analysis	Veron W. Ruttan October 1980
WP. 68	Technology for construction and maintenance of irrigation and drainage works in Egypt: a preliminary assessment	M.H. Amer October 1980
WP. 69	Development and application of indigenous low-cost technology to minimise water losses due to seepage in irrigation canals: the case of Bangladesh	A. Khair S. Sc. Dutt October 1980
WP. 70	Institutional aspects of the construction industry in developing countries	G.A. Edmonds October 1980
WP. 71	Market structures, industrial organisation and technology	D.J.C. Forsyth October 1980
WP. 72	Energy policy and the social objectives of development	C. Baron October 1980
WP. 73	Construction industry in Ghana	G. Ofori October 1980
WP. 74	Appropriate products, employment and income distribution in Bangladesh: a case study of the soap industry	A.K.A. Mubin October 1980
WP. 75	Technology policy and development financing: observations on some institutional constraints in Africa	B. Balkenhol October 1980
WP. 76	Farm equipment innovation for small-holders in semi-arid Kenya: a conceptual and empirical analysis.	G. Muchiri October 1980
WP. 77	Choice of appropriate technique in the African bread industry with special reference to Sierra Leone.	E. Chuta January 1981
WP. 78	Income redistribution, technology and employment in the footwear industry, a case study in Kumasi, Ghana	G.A. Aryee January 1981
WP. 79	A conceptual framework for the analysis of the effects of technological change on rural women	Ann Whitehead June 1981
WP. 80	Farm equipment innovations and rural industrialisation in Eastern Africa: An overview	B.F. Johnston July 1981
WP. 81	External development finance and choice of technology	A.G. Fluitman and J. White July 1981
WP. 82	Capital goods and technological change: some theoretical and practical issues from Africa	Thandika Mkandawire July 1981

WP. 83	Transport technology for the rural areas of India	National Council of Applied Economic Research, India July 1981
WP. 84	Implications of a basic needs strategy for the edible-oil industry	Radha Sinha, S.P. Sinha, G.P. Mishra and Gautam Pingle July 1981
WP. 85	New technologies in newspaper production in developing countries and their labour and social implications	Rex Winsbury September 1981
WP. 86	Technologies for rural women's activities - Problems and prospects in Sierra Leone	Y. Stevens October 1981
WP. 87	Rural women, their activities and technology in Ghana: An overview	Eugenia Date-Bah October 1981
WP. 88	Transport technology and employment in rural Malaysia	John D. Smith December 1981
WP. 89	Passenger transport in Karachi: a nested logit model	Mateen Thobani December 1981
WP. 90	The construction industry in Sri Lanka	S. Ganesan January 1982
WP. 91	Technology and employment in the capital goods industry in Ghana	A.A. Aboagye February 1982
WP. 92	Technological innovations in Korea's capital goods industry: a micro analysis	Linsu Kim February 1982
WP. 93	Market structure, industrial organisation and technology: Concepts, methods and evidence	J.L. Enos February 1982
WP. 94	The impact of income redistribution on technology and employment in the metal utensils sector of India	T.S. Papola and R.C. Sinha April 1982
WP. 95	National research systems and the generation and diffusion of innovations: the horticultural industry in Kenya	M.J. Dorling June 1982
WP. 96	Technical change in sugar cane harvesting - a comparison of Cuba and Jamaica, (1958-1980)	C. Edquist July 1982
WP. 97	Invention and the patent system in the Third World: Some policy issues	Susumu Watanabe July 1982
WP. 98	Institutional factors and technological innovation in North Vietnamese agriculture	Nguyen Ngoc Luu August 1982
WP. 99	Technical change and employment in the British Printing Industry	Bill Haywood September 1982
WP. 100	The Colombian capital goods industry and technological development	Zuleta, London September 1982

WP. 101	Technological Change, Production Organisation and Rural Women in Kenya	V. Ventura-Dias November 1982
WP. 102	Rural Transport in the Philippines: Jeepneys, Trimobiles, and other Simple Modes in Two Bicol Towns	Romeo B. Ocampo November 1982
WP. 103	Energy, employment and balance of payments - implications of technology choice in the energy and textile sectors in The Republic of Korea	Haider Ali Khan November 1982
WP. 104	Institutional constraints to the choice of appropriate construction technology	Stephen Drewer December 1982
WP. 105	The socio-economic implications of micro-hydro power systems in India	B.K. Joshi and R.C. Sinha December 1982
WP. 106	The effects of higher energy costs on the balance of payments, employment, technology choice and real incomes in Kenya	L.P. Mureithi, P.K. Kimuyu and G.K. Ikiara December 1982
WP. 107	Public enterprise, technology and employment in developing countries	Jeffrey James December 1982
WP. 108	The effects of oil price increases on the Egyptian economy	David Pearce and Ron Edwards December 1982
WP. 109	Role of rural institutions in the diffusion of agricultural innovations in Sri Lanka	H.M.G. Herath January 1983
WP. 110	Institutional factors and government policies for appropriate technologies: Survey findings in Indonesia, Thailand and the Philippines	Shinichi Ichimura January 1983
WP. 111	Market structure, industrial organisation and technological development: The case of the Japanese electronics-based NC-machine tool industry.	Susumu Watanabe February 1983
WP. 112	An approach towards integration of emerging and traditional technologies.	A.S. Bhalla J. James February 1983
WP. 113	The capital goods sector in Nepal: Present position and prospects	Koichi Niitsu, Keiichiro Hideshima, and Yasuko Wachi in collaboration with K.K. Vaidya March 1983
WP. 114	Technology, employment and development implications of new and renewable sources of energy (An analytical survey of current literature)	Andrew Mackillop March 1983

WP. 115	Woodburning Stoves: Their technology, economics and deployment	K. Krishna Prasad March 1983
WP. 116	Market structure, industrial organisation and technological development: The case of Egyptian industries	David J.C. Forsyth March 1983
WP. 117	Market structure and technology: Their inter-dependence in Indian Industry	Ashok V. Desai May 1983
WP. 118	The role of appropriate technology in a redistributive development strategy	Jeffrey James May 1983
WP. 119	Energy prices, development and the policy response in a small siege economy: Zimbabwe 1964-1981	John Suckling May 1983
WP. 120	Factors affecting agricultural research and technology - A case study of India	S.K. Mukhopadhyay June 1983
WP. 121	Public enterprises and the transfer of technology in the Ammonia industry	Brian Levy July 1983
WP. 122	Generation and diffusion of appropriate agricultural technology: A review of theories and experiences	Stephen D. Biggs and Edward J. Clay August 1983
WP. 123	The effect of oil price increases on the economy of Sudan with special reference to employment and income distribution	Ron Edwards, David Pearce and Janet Sladen September 1983
WP. 124	Institutional factors and technological innovations: the case of HYV rice in Bangladesh	Wahiduddin Mahmud and Muhammed Muqtada October 1983
WP. 125	Bureaucratic, engineering and economic men: Decision-making for technology in Tanzania's state-owned enterprises	Jeffrey James October 1983
WP. 126	The socio-economic impact of rural electrification in developing countries: A review of evidence	Fred Fluitman November 1983
WP. 127	Technology adaptation in mineral processing: A review of alternative iron and steelmaking technologies	D. Kaneko and E. Kurihara January 1984
WP. 128	Technology Adaptation and employment in the bauxite/alumina industry of Jamaica	Omar Davies, Carlton Davis and Dennis Morrison May 1984

WP. 129	Micro-electronics and employment in the Japanese automobile industry	Susumu Watanabe
May 1984
WP. 130	The socio-economic aspects of introducing solar flat plate collector technology in the Sahel	Jos. J.C. Bruggink
June 1984
WP. 131	Employment effect of micro-electronic equipment in the Brazilian automobile industry	José Ricardo
Tauile
August 1984
WP. 132	Commercial application of new indigenous technologies: a case study of Nepal	Madhab Raj Khoju
October 1984
WP. 133	Energy price increases and economic development in Malaysia	Fong Chan Onn
November 1984
WP. 134	Technology adaptation and employment in the agricultural tools and equipment industry of Bangladesh	Qazi K. Ahmad
Khandaker Rahman
Khan Md. N. Islam
Md. E. Ali
November 1984
WP. 135	The socio-economic impact of rural electrification in Malaysia	Chee Peng Lim
November 1984
WP. 136	Employment impact of micro-electronic 'new technologies' on the Italian automobile industry	Francesco Silva
Piero Ferri and
Aldo Enrietti
December 1984
WP. 137	Energy alternatives for irrigation pumping: An Economic Analysis for Northern India	Ramesh Bhatia
December 1984
WP. 138	Microelectronics and the technological transformation of the clothing industry	Kurt Hoffman and
Howard Rush
December 1984
WP. 139	The development of capital-goods sector: Experience of PRE-PRC China	Shigeru Ishikawa
January 1985
WP. 140	The technological behaviour of state-owned enterprises in Brazil	Alfonso Carlos
Correa Fleury
February 1985
WP. 141	The effects of external oil price increases and fuel price policies on the Peruvian economy	Alberto Pontoni
February 1985
WP. 142	Small-scale iron and steel processing in India	R.K. Koti and
N.P. Merchant
March 1985
WP. 143	Diffusion and commercialisation of technology prototypes: rice post harvest in Indonesia	V.R. Reddy
Faisal Kasryno
Masdjidin Siregar
April 1985

WP. 144	Micro-electronics, employment and labour in the North American automobile industry	Bruce T. Allen
April 1985
WP. 145	Energy consumption by income groups in urban areas of India	K.N.S. Nair and
J.G. Krishnayya
April 1985
WP. 146	The effects of oil price increases on the Colombian economy	Diego Otero in
collaboration with
Manuel Ramírez and
Alejandro Rincon
April 1985
WP. 147	The impact of increasing world energy prices on an export dependent economy: Zambia 1970 - 1982	John Suckling
April 1985
WP. 148	Comparative advantages of using sandcrete blocks and clay bricks in the construction industry in Sierra Leone: A preliminary analysis	Josie W. Elliott
May 1985
WP. 149	The energy and economic implications of agricultural technologies: an approach based on the technical options for the operations of crop production	Amulya K.N. Reddy
June 1985
WP. 150	Commercialisation of new indigenous technology in Jordanian agriculture	M.J. Dorling
S. Mutlu
July 1985
WP. 151	Photovoltaics: Socio-economic impact and policy implications	Douglas V. Smith
July 1985
WP. 152	Macro-economic effects and policy implications of higher oil prices in Costa Rica	E. Lizano and
A. Di Mare
August 1985
WP. 153	The employment and income distributional impact of microelectronics: a prospective analysis for the Third World.	J. James
September 1985
WP. 154	Energy and irrigation in India	C. Hurst
September 1985
WP. 155	Commercialisation of agricultural equipment generated by R & D system in Bangladesh	M.A. Jabbar
September 1985
WP. 156	Technological adaptation and employment in the small-scale farm machinery industry: Uttar Pradesh: India.	S.C. Mishra
October 1985
WP. 157	The Socio-economic impact of rural electrification in Algeria	A. Djeflat
November 1985
WP. 158	Technology choice, adaptation, and diffusion in privately- and state-owned enterprises in India	Anil B. Deolalikar
and
Anant K. Sundaram
December 1985

WP. 159	On technology blending	Nathan Rosenberg January 1986
WP. 160	Managing the commercialisation of solar energy technologies: A review of past experience in developing countries, and an analysis of future policy implications	Chris Hurst February 1986
WP. 161	Technology adaptation in mineral processing: The case of the copper industry in Zambia	Andrew Kanya, Iqbal Ali and Francis D. Yamba February 1986
WP. 162	Technological acquisition in the Thai rice milling and its related capital goods industry	Mingsarn Santikarn Kaosa-ard March 1986
WP. 163	Information Technology and services	Juan F. Rada March 1986
WP. 164	Technological Behaviour of Argentine Public Enterprises: The case of Yacimientos Petrolíferos Fiscales	Jorge Lucángeli April 1986
WP. 165	Technology Imports, Technological Learning and Self-Reliance in Tanzania	S. M. Wangwe April 1986
WP. 166	A New Approach to the Study of Technological Capability in Less Developed Countries	Martin Fransman June 1986
WP. 167	The Employment Effects of Microelectronics in the Office and Service Sector in the United States	Larry Hirschhorn and Alan F. Westin June 1986
WP. 168	The Employment Effects of Microelectronics in the UK Service Sector	Julia Swann July 1986
WP. 169	The impact of microelectronics-based technologies: The case of India	Amiya Kumar Bagchi September 1986
WP. 170	From restructuring to new technologies: Policies of a small European Country (Belgium)	J. G. Maton September 1986
WP. 171	Socio-economic impact of rural electrification in India	National Council of Applied Economic Research (NCAER) October 1986
WP. 172	The impact of microelectronics on employment and indigenous technological capacity in the Republic of Korea	Hak K. Pyo December 1986
WP. 173	Technology imports and indigenous technological capacity building: The Zimbabwean case	Daniel B. Ndlela March 1987
WP. 174	Market Structure and Technological Behaviour: A Study of the Edible Oils Industry in Perú	Francisco R. Sagasti April 1987

WP. 175	Implications of Microelectronic Technologies for Labour and Employment in the Banking and Retail Industries in Australia	John Hill May 1987
WP. 176	The Differential Impact of New Technologies on Developing Countries: A Framework of Analysis	Amiya K. Bagchi June 1987
WP. 177	Institutional Aspects of Promoting Renewable Energy Technologies in India	Ramesh Bhatia October 1987
WP. 178	Diffusion of Renewable Energy Technologies in India: A Case Study of Biogas Dual Fuel Engines	Ramesh Bhatia October 1987
WP. 179	Profil et capacités technologiques des micro-entreprises du secteur métallique de Kigali et Butare (Rwanda)	A. Barampama October 1987
WP. 180	Capacité et maîtrise technologique des micro-entreprises métalliques à Bamako et a Ségou (Mali).	J. Capt October 1987
WP. 181	Institutional Aspects of Promoting the Use of Water Turbines in Nepal	S. N. Sharma October 1987
WP. 182	The Impact of Microelectronics on Employment in Japanese Offices and Service Industries	Yasuo Kuwahara October 1987
WP. 183	Microelectronics-based innovations and employment in Mexican industries	L. Dominguez-Villalobos January, 1988
WP. 184	The Impact of Technology Imports on Indigenous Technological Capacity: The Case Study of Mexico	Dilmus D. James January 1988
WP. 185	Technology Import and Indigenous Technology Capacity Building in China	Shigeru Ishikawa January 1988
WP. 186	Importation de technologie et developpement des capacites techniques dans l'industrie Algerienne	F. Yachir January 1988
WP. 187	Learning and the accumulation of technological capacity in Brazilian pulp and paper firms	D. Scott-Kemmis February 1988
WP. 188	The impacts of microelectronics on employment and income in the Brazilian metal-engineering industry	A. Fleury February 1988
WP. 189	Domestic learning, international technology flows and the world market: New perspectives for the developing countries	F.C. Sercovich February 1988
WP. 190	Biotechnology to combat malnutrition in Nigeria	Gilbert U. Okereke November 1988
WP. 191	Biotechnology and labour absorption in Malawi agriculture	C. Chipeta and M.W. Mhango December 1988

- WP. 192 Industry-university relationship and biotechnology Gerardo Otero
in the dairy and sugar industries: Contrast January 1989
between Mexico and the United States
- WP. 193 Biotechnology trends: A threat to Philippine Saturnina C. Halos
agriculture? January 1989