WORLD EMPLOYMENT PROGRAMME RESEARCH

Working Paper

Technology and Employment Programme

**ADVANCED PLANT BIOTECHNOLOGY IN
MEXICO: A HOPE FOR THE NEGLECTED?**

by

Amarella Eastmond and
Manuel L. Robert

35463

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

March 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 92-2-107021-2

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 WEP Technology and Employment Programme, this study is the eighth in a series on the potential socioeconomic and employment effects of specific biotechnologies in developing countries.¹ The other case studies cover advanced plant biotechnologies in Kenya and Malawi, dairy (Mexico and the United States) and animal feed (Nigeria) industries, and edible plant-oils processing. Another study looks at the inter-sectoral employment and output implications of biotechnology developments in an input-output framework. A case study on the Philippines examines the impact of external developments on the workforce critically dependent on the export crops for their livelihood.

This inter-disciplinary study by Ms. Amarella Eastmond, Researcher in the Social Science Unit of the Autonomous University of Yucatan and Manuel L. Robert, Head of the Division of Plant Biology of the Centre for Scientific Research of Yucatan essentially attempts to test the broad hypothesis that contrary to the Green Revolution, the Advanced Plant Biotechnology (APB) has the potential to improve all crops in all types of ecological areas (in particular poor agricultural lands) and that, therefore, it also has the potential to benefit the whole size range of farmers and not just the large ones.

For the purpose of this study, APB refers to the techniques developed over the past 20 years to manipulate plants in the laboratory to include both cell biology (tissue culture) and the molecular biology (recombinant DNA) techniques. The study focuses on a neglected ecologically unfavourable region of Mexico growing long-term perennial cash crops of critical importance to the livelihood of the poor totally unaffected by the Green Revolution.

Application of APB to the citrus crop would be saving on the costs of chemical means of disease and pest controls for small farmers of the southeast (who constitute nearly 98 per cent of the total growers). Use of APB to produce virus-free citrus material would substantially reduce crop losses (currently 50 per cent) due to pests and diseases at a relatively low cost. Since APB will initially focus on disease-free material, it will not displace labour in the most labour-intensive operations of weeding, pruning and irrigation. Moreover, any loss in employment in disease and pest control will be more than compensated by the greater labour input for harvesting and transport of the larger output. The authors conclude that APB offers the possibility of intensifying growers' incomes, providing more work for the day labourers, reducing excess capacity in the juice processing plant (increasing, thereby, industrial jobs) and stimulating the local economy. However, the past trend of increasing social differentiation may be further aggravated.

Application of APB to henequen (a natural fibre used to manufacture rope and twine) could raise productivity and the increased supply of quality plantlets through micropropagation techniques could boost the incomes of low paid field workers (nearly a quarter of Yucatan's economically active population depend on this crop for their employment).

1. See WEP 2-22/WPs. 190, 191, 192, 193, 194, 195, 199 and 200.

The application of APB offers a cheaper and certainly more environmentally-sound alternative to the chemical control of the leaf rust in coffee through the micropropagation of resistant varieties in the southeast of Mexico. Duly supported by a credit programme and an appropriate pricing policy, APB could protect the livelihood of the 93,000 small producers (accounting for 75 per cent of the total) and a large proportion of the 270,000 day labourers engaged in coffee cultivation. By substantially increasing yields, APB could also raise wages as well as the number of rural jobs. Similar to the crops above, the diminished labour use in the application of chemicals could be more than compensated by increases in employment in other farm operations and through the forward linkages to the coffee processing industry.

Finally, application of APB to controlling the disease, lethal yellowing in coconut plantations would provide an important secondary source of employment and incomes to the rural poor.

Iftikhar Ahmed

ABBREVIATIONS

APB	Advanced plant biotechnology
BR	Biorevolution
DCs	Developed countries
EAP	Economically active population
GR	Green Revolution
HYV	High yielding variety
LDCs	Lesser developed countries
LY	Leathal yellowing
MLO	Mycoplasma-like organism
R&D	Research and development
PTC	Plant tissue culture
PVC	Polyvinyl chloride
TC	Tissue culture
TW	Third World

ABBREVIATIONS OF INSTITUTIONS

ANAGSA	Aseguradora Nacional Agrícola y Ganadera National Agricultural Insurance Company
CEPAL	Comisión Económica para América Latina Economic Commission for Latin America
CICY	Centro de Investigación Científica de Yucatán Centre for Scientific Research of Yucatan
CINVESATV-I	Centro de Investigaciones y Estudios Avanzados, Unidad Irapuato Centre for Research and Advanced Studies, Unit for Agricultural Biotechnology in Irapuato
CONACyT	Consejo Nacional de Ciencia y Tecnología National Council of Science and Technology
CONAFRUT	Comisión Nacional de Fruticultura National Fruit Commission
CORDEMEX	Cordeles Mexicanos, S.A. de C.V. Mexican Twines
CP	Colegio de Postgraduados, Chapingo Postgraduate College, Chapingo
FAAPY	Fondo de Apoyo para las Actividades Productivas de Yucatán Fund to Support Productive Activities in Yucatan
FERTIMEX	Fertilizantes Mexicanos, S.A. Fertilisers of Mexico
FIRA	Fideicomiso para el Desarrollo Agropecuario (del Banco de Mexico) Fund for Agricultural Development, Bank of Mexico
INEGI	Instituto Nacional de Estadística, Geografía e Informática National Institute of Statistics, Geography and Information
INMECAFE	Instituto Mexicano del Café Mexican Institute of Coffee
IRHO	Institut français pour les huiles et oléagineux
ORSTOM	Institut français de recherche scientifique pour le developpement et coopération
PRONASE	Productora Nacional de Semillas National Seed Producer
SARH	Secretaría de Agricultura y Recursos Hidráulicos Ministry of Agriculture and Water Resources
SPP	Secretaría de Programación y Presupuesto Ministry of Programming and Budget
UACH	Universidad Autónoma de Chapingo Autonomous University of Chapingo

TABLE OF CONTENTS

	<u>Page</u>
PREFACE	
ABBREVIATIONS	
ABBREVIATIONS OF INSTITUTIONS	
INTRODUCTION	1
THE METHODOLOGY	3
THE INSTITUTIONAL AND TECHNOLOGICAL SETTING	5
The Green Revolution	5
The Bio-revolution	6
ADVANCED PLANT BIOTECHNOLOGY (APB)	7
Methods and general applications of APB	7
Micropropagation	7
Production of disease-free stocks	7
Germplasm preservation	8
Generation of genetic variability	8
APB in Mexico	9
THE SOUTHEAST OF MEXICO	11
Peasant agriculture	12
ANALYSIS OF SELECTED CROPS	13
Citrus in Yucatan	13
Production problems	16
Employment and income from citrus	18
State of the art: APB	22
Socioeconomic impact	25
Henequen	26
State of the art: APB	28
Socioeconomic impact of APB	28
Coffee	29
Employment and production systems	29
Orange leaf rust disease	31
State of the art: APB	32
Socioeconomic impact	33

Coconut	34
Lethal Yellowing (LY)	35
State of the art: APB	36
Threats of substitution	37
Socioeconomic impact	38
 FUTURE POTENTIAL OF APB IN MEXICO	 38
Obstacles to the development of APB in Mexico	39
Comments on the selected crops	42
Conclusions	43
 NOTE ON CITRUS GROWERS' INCOME	 45
 REFERENCES	 46

ADVANCED PLANT BIOTECHNOLOGY IN MEXICO: A HOPE FOR THE NEGLECTED?

INTRODUCTION

Contrary to the Green Revolution (GR), advanced plant biotechnology (APB) is said to have the potential to improve all crops in all types of ecological areas (in particular poor agricultural lands) and that therefore it also has the potential to benefit the whole size range of farmers and not just the large ones. If this is the case, how likely is it that the new technology will indeed reach the poor farmers of the Third World (TW), under what circumstances and what impact will it have?

In this study we pose these questions and attempt to answer them with reference to an agriculturally marginal region of Mexico: the southeast. We have chosen to focus on this area (composed of the states of Chiapas, Campeche, Quintana Roo, Tabasco and Yucatan see map 1) because it contrasts markedly with the more economically and ecologically privileged northern states. Instead of basing our analysis on speculation about the promises of APB, we select some important crops in the region, describe them briefly in agronomic and social terms and discuss how APB could be applied to improve them, how likely this is and what the impact might be on rural development.

There is a growing literature on APB and its potential to transform living and working conditions as humanity approaches the 21st century. Much of it is highly technical in its approach and analyses what is and will be scientifically and technologically feasible in the short, medium and long terms in the way of "designing" crops better adapted to particular needs. Another distinct section of the literature deals with the probable implications of these scientific and technological advances for different regions of the world, emphasising the relative advantages and disadvantages for industrialised countries and the Third World. This separation of the social and natural science perspectives in assessing APB impact has led to the tendency to oversimplify and overgeneralise. Too often small technical successes have been blown up and extrapolated to a wide range of situations, while social, economic and political limitations have been underestimated. An alternative approach, which we have selected here, is to combine the two perspectives as far as possible and focus on one particular area. This too, of course, has its limitations but at this stage in the APB debate it would seem necessary to take a closer look at some specific cases.

Unlike the fertile but arid northern states, the southeast is overwhelmingly composed of tropical lowlands and is considered marginal for agricultural purposes: over 98 per cent of its agriculturally useful surface depends solely on rainfall for its water supply and with the exception of Tabasco, the five states are amongst the poorest in the country. They contain some of the highest concentrations of ethnic groups. With such strikingly different ecological and socioeconomic characteristics, GR technology, designed for the north, proved inadequate for modernising agriculture in the southeast which, until recently, was still dominated by cattle ranching, subsistence slash-and-burn production of maize and beans and plantation crops: sugarcane, henequen (sisal), coffee and coconut.

Average yields of basic food crops in the southeast have always been low but in the last 10 years three diseases (leaf rust, black sigatoka and lethal yellowing) have begun to destroy coffee, bananas and coconuts respectively, widening the gap between potential and actual yields and, in some cases, forcing producers to abandon the crops. In all cases, producers' incomes have

Map 1

The southeast of Mexico

been seriously reduced and agricultural day labourers have frequently been obliged to migrate to more productive rural areas or the cities to join the under- and unemployed, urban, labour reserves. Theoretically, the application of APB to the above crops could go a long way to combat the diseases and increase yields, thereby representing enormous benefits to the producers and rural workers, and all those who directly and indirectly depend on them for their livelihoods.

We argue that the impact of APB, like other technologies, is not inherently negative or positive. It has the capacity to open doors but there is an element of choice in whether one crosses their thresholds or not. Moreover, although there may be discernible general trends, the precise socioeconomic effects of APB will depend on who develops the technology, how it is developed and for whom. If we are correct in these assumptions, then particular historical, cultural and political circumstances are important in determining the role APB may play in the future development of a country. Any analysis should, therefore, regard context specificity and sensitivity to local conditions as central issues, that is, it should be based as much on past experience as on theoretical considerations. Hence in this study, where possible, considerable attention is paid to outlining the relevant historical, political and social fabric with which plant biotechnology will interact.

The difficulties and complexities of assessing the probable impact of new technologies on society cannot be underestimated. Some people have even gone so far as to say that technology forecasting is a fool's game in that no one "can seriously claim to be completely objective when judging a vast range of often non quantifiable information and future perceived expectations on the social role of a given technology" (Standke, 1987). We recognise the impossibility of achieving absolute objectivity in our assessment of APB on the southeast of Mexico. An inevitable degree of moral judgement creeps in when one examines the distribution of benefits and losses. A benefit to one producer may well turn out to be harm to another through a change of price of his product or through the loss of his comparative advantage. The benefits to the region from the creation of a vast number of minimum wage jobs, on the other hand, are at least debatable if they arise out of more sophisticated institutional and employment structures whose ultimate consequence is to convert small producers into wage labourers rather than increasing their production potential.

THE METHODOLOGY

Many authors have drawn comparisons between the Green Revolution and the Bio-revolution (BR) and pointed to the analytical usefulness of the experience of the former as a baseline from which to make predictions regarding the probable impact of the latter (Buttle et al., 1985, Ahmed, 1988). The Rockefeller Program, which gave rise to the GR began in Mexico in the 1940s and numerous ex post evaluations of the Mexican experience at a national level exist. Hewitt de Alcantara's study Modernising Mexican Agriculture (1976) is an excellent account of the structural changes during the 1940-1970 period based on the agriculturally fertile region of the north of the country. It has not been possible for us to follow this approach for the southeast, however, for four main reasons. First, as de Alcantara demonstrates, structural changes in Mexican agriculture after Cárdenas' massive land reform in 1938 were fundamentally the result of rural development policies designed to favour commercial agriculture and not small-scale peasant production. GR technology, a term she carefully avoids, can be seen to compound the polarising effect of government policy but it is not the underlying causal factor.

Second, the southeast was only marginally affected by the GR because of the technology's inadequacy for its main crops and its tropical ecological conditions. The GR produced high-yielding varieties (HYVs) for only one group of crops - cereals - for cultivation under specific conditions: high input, temporal systems. It is even dubious whether the term GR is appropriate in the context of the modernisation of the southeast in that what improvements there have been are not largely attributable to HYV but to better management. The level of improved seed sales in Yucatan have been very low and the sales have hardly increased over the past 10 years. In 1985 more "criolla" (selected wild varieties) seed was sold than of improved varieties.

Third, APB will affect a wide range of traits in a large number of crops cultivated under all sorts of agricultural and ecological conditions. It is therefore necessary to consider each crop and each region separately before making generalisations.

Fourth, intensification of agriculture in the region has been too recent to be adequately reflected in the official statistics. The tropical lowlands were not even cleared for modern agriculture until the 1960s and the more remote zones did not begin to use modern technology until the beginning of the 1980s. On the other hand, the last agricultural census was carried out in 1970 and the more recent official data on population and agricultural production leaves out much of the necessary socioeconomic information. Thus only the earlier official data exist for an evaluation of the modernisation of agriculture in the southeast.

In the absence of a case study as a model the lack of existing applications of APB to evaluate, our approach is somewhat empirical and consists of the following steps:

1. Definition of the region of study (the southeast).
2. Identification of the main crops of the region (based on area, production and value) and selection of a few crops for closer study.
3. Identification of the principal yield-reducing factors for each crop.
4. Evaluation of Mexico's APB research capability and government policy with respect to its target beneficiaries.
5. Analysis and speculation on how APB could affect each crop.

In order to make some judgement about possible future impact we make the following assumptions:

1. APB produced in developed countries (DCs) is directed to solving their own problems and maximising profits so that it will have little application in less developed countries (LDCs). It is unrealistic to assume that much public or private research will be carried out purely on humanitarian grounds to help the Third World. The lack of support from the United States, Japan and most of Europe for the UNIDO-sponsored International Centre for Genetic Engineering and Biotechnology illustrates this point (Joffe and Greeley, 1987).
2. If any benefits are to be derived from APB for the Third World, each country will have to do its own research and development.

As a result of the initial analysis of crops based on these assumptions we selected four: citrus, henequen, coffee and coconut which share the

characteristics of being long-term perennial cash crops, of importance to Mexico and on which research projects that could lead to eventual application of APB, are being carried out in the country.

THE INSTITUTIONAL AND TECHNOLOGICAL SETTING

As a result of nearly 50 years of neglect of the peasant sector, Mexican agriculture has become markedly polarised. On the one hand, it consists of a small number of large prosperous commercial farmers (probably no more than 2 per cent) mostly situated in the north of the country, and producing high value crops and increasingly oriented to the export market. On the other hand, it consists of a vast number of small, resource-poor peasant producers located predominantly in the central and southern regions whose limited capital has prevented them from increasing their productivity to any significant degree and hampers their choice of crops. The very poor still depend heavily on maize and beans partly for home consumption and partly for sale in the local market.

The main form of control, especially over peasant producers, is through the supply of credit. It is insufficient in quantity for the number of producers and involves a great deal of red tape. In addition, it is granted as a package which includes seeds, fertilisers, pesticides, etc. (deducted at source) in the quantity and quality that the authorities deem appropriate for the credit beneficiaries. It is also accompanied by regular inspections from SARH and Banrural agronomists, whose job it is to check that all the production recommendations, rules and regulations regarding credit are satisfactorily complied with.

Over the years such massive intervention has resulted in the build up of an overgrown, inefficient, paternalistic bureaucracy which has neither the resources to carry out its basic functions adequately nor the structural flexibility to change, allowing the producers to become more independent and self-sufficient. If APB is to be adopted, it is clear that the government will have to restructure both the institutions and the mechanisms for intervening in agricultural production.

The Green Revolution

The distributional effects on Mexican agriculture brought about by the country's key development policy of import substitution, were compounded by the impact of the GR. It is perhaps no coincidence that Mexico is the birth place of the high-yielding varieties of maize and wheat that were to profoundly change Third World agriculture. Two impacts stand out as crucial legacies of the GR. First, the demonstration of just how powerful a tool Western science and technology can be when harnessed and directed towards attacking a specific problem; in this case, low agricultural productivity and a shortage of food supplies. Wheat yields were made to increase from an average of 754kg per hectare in 1940 to 3,108kg in 1970 and 4,105kg in 1980. Maize yields, although less spectacular, increased from an average of 602kg per hectare in 1940 to 1,207kg in 1970 and 1,823kg in 1980 (Rodriguez Vallejo, 1988).

The second impact was less noticeable initially but was equally profound: a paradigm shift in agricultural thinking. The GR provided the vehicle for introducing and superimposing the concepts and technology of industrial agriculture on what was still essentially a tradition-bound peasant agricultural base. Thus, the goals of efficiency and productivity began to

replace the time-honoured ideals of family food security based on family labour and the sacredness of nature. How conscious this imposition of cultural values was is debatable, given that the Rockefeller Foundation and its leading scientists were, according to their own reports, motivated by the humanitarian concern of "increasing food supplies as quickly and directly as possible by means of the genetic and cultural improvements of the most important food and feed crops ..." (Stakmann et al., 1967, p. x).

It is arguable, in the light of the fierce debate on the ownership of germplasm (Kloppenborg and Kleinman, 1987) and its importance for the BR that there was a further reason motivating American scientists to explore Third World countries such as Mexico: their rich germplasm resources. Given the enormous diversity and richness of the Mexican and Central American germplasm base (Mexico is the Centre of Origin of maize, beans, tomato, chile, squashes and cacao) and the poverty of the North American one, it is hardly surprising that Americans were so keen to collect local varieties. Though Mexico undoubtedly benefited from the breeding programmes developed by the Rockefeller Foundation, it is an open question as to who gained most, especially when seen in the long-term perspective of APB.

The Bio-revolution

The Bio-revolution offers far greater human control over agricultural production than has even been possible before. As such, it is a leap in the direction of industrialising agriculture which, more than any productive activity, has so far resisted integration into capitalist logic (Kloppenborg, 1984) imbuing it with similar objectives as those used in industrial processes: uniformity of production, massive production scale, maximisation of profits, reduction of costs, particularly those of labour and energy-based inputs, production quality and market differentiation, centralisation and vertical integration of the production process. Such criteria are likely to clash even more violently with peasant cultures and small-scale production techniques and individual decision-making than those of the GR. However, APB has far greater theoretical flexibility than its scientific predecessor and although there are undoubtedly strong pressures for it to follow the industrialisation trends, there are also possibilities for it to reduce production costs. As a result, the scope of its potential impact is immediately widened to cover small producers cultivating marginal lands. However, its potential in this respect will only be realised if policies are forged to direct it differentially to different scales of production.

ADVANCED PLANT BIOTECHNOLOGY (APB)

To differentiate advanced plant biotechnology from the traditional horticultural and agronomical practices that also fall into the broader definition of plant biotechnology, we shall refer to it here as all those techniques developed over the past 20 years to manipulate plants in the laboratory. APB therefore groups both the cell biology (tissue culture) and the molecular biology (recombinant DNA) techniques employed to improve the performance of plant species for the benefit of mankind.

APB is based on the possibility of culturing plant cells, tissues and organs in test tubes and of redifferentiating new plantlets from them with superior characteristics. This improvement can be brought about by techniques as simple as the cloning of elite individuals or as sophisticated as the introduction of a gene from a completely different organism such as a bacteria.

Some authors (Kenney and Hibino, 1987) centre their analysis of APB around genetic engineering. Although, in the long run, the techniques of molecular biology will no doubt have the greatest impact, we believe that in the short term and specifically for developing countries, tissue culture techniques have more to offer because they are cheaper and easier and are more widely applicable to a greater number of crops.

Methods and general applications of APB

Plant biotechnology contributes to the improvement of crops in four principal ways described below.

Micropropagation

This is the large-scale clonal multiplication of plants with specific desirable traits. At least in theory, thousands or even millions of plants, genetically identical to the mother plant, can be produced in the laboratory.

The advantages offered by the process are:

1. rapid, large-scale propagation;
2. genetic homogeneity;
3. reduced space; and
4. in some cases, as an extra bonus, micropropagated plants grow faster or are more vigorous than parental stocks.

The disadvantages are:

1. higher production costs;
2. genetic instability (depending on the method); and
3. appearance of juvenile traits or early flowering that might be a serious problem in some species.

Micropropagation is advantageous for almost every species (George and Sherington, 1984) but offers unique options for the manipulation of those with long life cycles or inefficient propagation mechanisms. So far however, commercial applications have been restricted to high value species such as foliage and cut-flower ornamentals.

It is very important to stress that efficient micropropagation systems are essential prerequisites in order to reap the benefits that can be obtained from the other APB methods.

The in vitro multiplication of plants can be achieved from one of two main routes:

1. the formation of adventitious shoots and roots (organogenesis) from somatic tissues; and
2. the induction of somatic embryos (embryogenesis) from somatic cells and tissues.

Production of disease-free stocks

The symptoms of a virus disease are not always obvious in the early stages of a plant's development and the unconscious multiplication of infected

parental material is a very serious agricultural and horticultural problem since all the individuals derived from that stock will eventually manifest the disease. The cultivation of tissues combined with thermal and chemical therapies is a very efficient way to produce "clean" plants free of all sorts of pathogens such as virus, viroids fungi and bacteria.

The isolation and in vitro culture of apical meristems (growing tips) has been widely applied to generate plants that are free of the viruses present in the leaves or stems of the mother plant.

The disease-free stocks must be checked by immunological and molecular techniques to certify the absence of virus and viroids. In most cases, the plants are also free of bacteria and fungi.

Germplasm preservation

In vitro cultured tissues and organs can be preserved at low temperatures and stored for long periods of time without losing their regeneration capabilities. These methods will contribute to solving some of the difficulties existing in today's germplasm banks, such as the preservation of "recalcitrant" species whose seeds cannot be stored without losing their viability, or the storing of large numbers of samples in a limited space without the risk of losing them to disease or pests. Continuous replanting and production of seeds is also avoided, with a consequent reduction in labour and costs.

Generation of genetic variability

The most promising and publicised application of APB is the generation of new varieties. Through traditional methods this is a painful and lengthy process that implies the planting and analysis of thousands of individuals in large fields. By using APB it is possible to considerably reduce the time span of the process and to select among thousands of individuals for a specific trait in the test tube. Even more significant is the possibility to add single specific traits to varieties of proven agricultural merit without mixing its valuable characteristics. Among the traits that are expected to be produced by APB are:

- resistance to pathogens such as fungi and viruses;
- resistance to stress such as salinity, metal toxicity, drought, heat and frost;
- resistance to pests;
- resistance to herbicides; and
- increased yield through improved photosynthesis and biological nitrogen fixation.

The main techniques through which APB can contribute to the production of new varieties are:

- culture of gametic cells for the production of homozygous plants;
- selection of somaclonal variants;
- production of somatic hybrids through protoplast fusion;
- embryo rescue to facilitate wide crosses; and
- genetic engineering.

Culture of haploid (gametic) cells: Pollen and ovules have half the number of chromosomes present in all the other tissues of a plant. By chemical treatment this number can be doubled so that the plants redifferentiated from these cells have two sets of identical chromosomes and therefore two sets of identical genes. These homozygous plants are very useful in searching for mutants and for breeding programmes (for review see Bajaj, 1983).

Somaclonal variation: Genetic changes normally appear in plants regenerated from cultures or redifferentiated tissues (calli). These variants are easily obtained and show a broad range of useful agricultural traits. If the cells are cultured in the presence of a selective agent, such as a pathogen toxin, only those cells that are resistant to it will survive and the plants regenerated from them often express the new characteristic (for review see Evans and Sharp, 1986).

Protoplast fusion: By an enzyme treatment plant cells can be stripped of their rigid cell walls. These "naked" cells, called protoplasts, can once remake their cell walls, divide and give rise to complete plants. Any genetic modification suffered by the protoplasts will be inherited by all the cells of the new plant.

If two protoplasts from two varieties or species are fused by means of a chemical or electrical influence, the resulting cell and the plants derived from it, will be hybrids. Since the natural barriers that restrict sexual reproduction to close relatives do not operate here, these somatic hybrids offer the possibility of introducing genes from wild relatives into cultivated varieties (for review see Cocking, 1988). These wide crosses frequently need the help of an additional technique:

Embryo rescue: The embryos produced from wide crosses are often incapable of germinating. If removed from the seed and helped with abundant nutrients and growth regulators, they germinate and form whole plants (for review see Hu and Wang, 1986).

Plant genetic engineering: This is the introduction into plant cells of isolated genes that confer specific new traits to the cells and to the plants regenerated from them. It makes use of recombinant DNA techniques for the identification, isolation and cloning of genes and their recombination with other genes to make them functional within the recipient plant (for review see Kingsman and Kingsman, 1988).

It is very important to stress that these techniques are a useful complement but they in no way substitute the breeder's work and field trials. For this reason it is fundamental to ensure an adequate link between research in the laboratory and crops grown in the field.

APB in Mexico

Plant biotechnology started to be developed in Mexico early in the 1970s in the Colegio de Postgraduados of Chapingo and in the Faculty of Chemistry in the National Autonomous University of Mexico (Robert y Loyola, 1985). Soon after, new research centres were created for plant biological research: The Centro de Investigaciones y Estudios Avanzados established a unit in Irapuato to do research on agricultural biotechnology (CINVESTAVI); the National Autonomous University created the Centre for Nitrogen Fixation Research (UNAM-CIFN) and CONACyT created the Centre for Scientific Research of Yucatan (CICY) in Merida, indicating the authorities' interest in the field.

There are a considerable number of laboratories already working on PTC in the country and their studies cover a large range of species. Although most projects are concerned with micropropagation methodologies, the field has diversified and now includes germplasm preservation, the production and indexation of virus-free plant stocks, biosynthesis through in vitro cultured cells and plant genetic engineering.

The lists of institutions, human resources and public funds involved in plant biotechnology in Mexico, cited in previous reports (Robert and Loyola, 1985; Cepal, 1988), appear to be considerable at first glance for a developing country. This has tended to give rise to an overoptimistic evaluation of the field's potential to bring about radical change in Mexico's capacity to feed itself and export agricultural products. However, this compilation is based on the stated objectives of the research projects, without examining too closely the institutions' real capabilities and the projects' probabilities of being scaled up and transferred to the private or public productive sphere.

Taking into account their scientific staff, research infrastructure and links with agricultural producers and private enterprise, there are only a few institutions in Mexico that have the capacity to achieve this in the short term (Eastmond et al. in preparation). It should be noted that in the discussion that follows, reference is made solely to those aspects of the institutions that are concerned specifically with APB.

Centro de Investigaciones y Estudios Avanzados (CINVESTAV) Unidad Irapuato

This centre has the largest number of highly-qualified researchers (around 15 Ph.Ds) and the best-equipped installations for APB. The Centre has received strong political backing from the Federal Government and the State of Guanajuato. It is the only centre in Mexico with the capacity to carry out plant genetic engineering which has been assigned top priority in the institution's work. The department of genetic engineering has a large range of ambitious projects on the genetic improvement of various species such as maize, rice, beans, tobacco, amaranth, tomato and chili.

Centro de Investigación de Yucatan (CICY)

The Division of Plant Biology carries out basic research on plant biochemistry, physiology and genetics of important crops and potentially useful in vitro cell systems. Its relatively small research staff (five Ph.Ds and three MScs) has developed considerable expertise in plant biotechnology particularly on biosynthesis and on micropropagation of a variety of species including agaves, marigolds and several ornamentals. CICY has established important links with private industry with which it has a number of contracts. Some of the projects are now being transferred and plants are being tested in the field. The centre is building a pilot micropropagation laboratory to be able to scale up processes to semi-commercial levels which it is hoped will contribute to linking research with commercial needs and therefore stimulating greater interest from private industry.

Colegio de Postgraduados (CP) and the Universidad Autonoma de Chapingo (UACH)

Chapingo, the main agricultural centre in the country, has two distinct institutions that carry out research and teaching in APB: the Universidad Autónoma de Chapingo (UACH) which confines its teaching to undergraduates and the Colegio de Postgraduados, in charge of the postgraduate facilities in the area. Both institutions are closely related to the Ministry of Agriculture and are therefore closer to the agricultural problems of the country than any other research institution. UACH has specialised in micropropagation of a variety of species among which coffee is of particular relevance (see below) and through a collaboration with SARH's own research institution, INIFAP, on the production of virus-free potatoes. The Colegio de Postgraduados has good research facilities and a long list of projects aimed at genetic improvement and basic research.

The tissue culture laboratory of the Instituto de Biología (UNAM) has done important work on genetic conservation and has links with private industry.

As can be seen in Table 1, the Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias (INIFAP) has created several laboratories which are working on APB. In spite of their importance, since they form part of the agricultural research system, they do not have sufficient financial backing. They therefore suffer from limited facilities and staff.

Very high quality basic research in plant biochemistry and molecular biology is also done at some institutions among which the most prominent are the Centro de Investigación sobre Fijación de Nitrógeno (UNAM CINF) in Cuernavaca and the Departamento de Biología Vegetal in the Faculty of Chemistry, UNAM. In addition, there are a few laboratories exploiting APB for commercial purposes on a small scale. Their work is limited to the high value market of ornamental flowers. Most other laboratories are of recent origin and are small, understaffed and inexperienced, concerned mainly with teaching.

THE SOUTHEAST OF MEXICO

The southeast is spatially peripheral and ecologically and economically underprivileged in comparison with the central and northern regions of the country. In spite of the region's low productivity, it has some economically important crops, particularly coffee, coconuts, cacao, bananas and oranges. The southeast produces almost 100 per cent of the national cacao production, 33 per cent of the national coffee harvest, 30 per cent of the bananas, and 25 per cent of the copra. The inefficient production systems can partly be explained in terms of smallness of scale and poor management but they are also a result of insufficient research and funds devoted to improving production technology. All the crops in the southeast have low yields. In addition, coffee, bananas and coconut are afflicted by very specific diseases which contribute significantly to widening the gap between actual and potential yields. Theoretically, the application of plant biotechnology could go a long way to solving these specific problems and to increasing yields but enormous economic obstacles stand in the way.

Based on the 1970 agricultural census, Cepal (1982) classified Mexico's agricultural producers into three main categories: peasants, transitional producers and entrepreneurs, representing 86 per cent, 11.6 per cent and 1.8 per cent of the total respectively. It is likely that these percentages have not changed substantially. It gives an indication of the poverty and low technological level of the majority of Mexico's farmers and the challenges which the country faces in trying to improve its production, productivity and the living standards of its people. However, agriculture in the southeast, is a satisfactory source of livelihood for only a small fraction of those who practise it, most of the farmers being underemployed (underemployment is defined as receiving less than the minimum wages). The 1970 agricultural census (Coll-Hurtado, 1985) indicates the following percentages for the southeast:

	% Underemployed
Campeche	75-89
Chiapas	> 90
Quintana Roo	60-70
Tabasco	75-89
Yucatan	> 90

The most important crops in terms of value and cultivated area are grasses and maize which are grown in the above five states of the southeast.

The latter is the basis of peasant agriculture and is briefly discussed below but is to be affected by APB in the near future. Of the remaining crops we selected citrus and henequen because of their significance in Yucatan, and coffee and coconut because of their more general relevance at a national level due to their high value and the present threat posed by diseases.

Table 1

Principal institutions working on APB in Mexico

-
1. Centro de Investigación Científica de Yucatán (CICY).
 2. Centro de Investigaciones y Estudios Avanzados, Unidad Irapuato (CINVESTAV-I).
 3. Colegio de Postgraduados de Chapingo, Chapingo (CP).
 4. Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias (INIFAP).

Experimental stations at: Campeche
Nuevo León
Tabasco
Toluca
Zacatepec

5. Universidad Autónoma de Chapingo (UACH).
6. Universidad Nacional Autónoma de México (UNAM)

Instituto de Biología, Jardín Botánico (IB-JB)
Facultad de Química, Depto. de Bioquímica Vegetal
Centro de Investigaciones sobre Fijación del Nitrógeno (CIFN).

Peasant agriculture

Peasant agriculture is based on maize and beans which are by far the most important crops for the Mexican diet. Although most peasants today carry out mixed agriculture, combining food crops for home consumption with cash crops such as coffee, or fruit and vegetables to sell on the local market and some animals in their backyard, it is still rooted in traditional slash and burn practices.

The slash and burn cycle begins with the clearing of a patch of secondary vegetation. A peasant will select his plot from the communal lands on the basis of distance from his home, age of the vegetation and soil fertility. (Under the harshest ecological conditions an area ideally should be left uncultivated for 15 to 20 years before being reused.) The scrub vegetation is cleared, burned and the area is sown with maize intermixed with beans just before the rainy season begins in May or June. Some fruit and vegetables may also be inter-cropped. The harvest is carried out sometime in August or September. The same area may be used for two consecutive years but thereafter, yields drop dramatically, and the plot is usually abandoned. The average maize yields are very low (around 1,300kg per hectare) except in

Chiapas and are very uncertain. When they can afford it, peasants will apply small doses of fertilisers to increase their chances of obtaining a harvest. Peasant families cannot be sure of obtaining sufficient food from their traditional agriculture alone. They are increasingly being pushed off the land by the low returns to their labour, the low guarantee prices for basic food crops (depressed by the government in an attempt to control inflation and prevent rising urban salaries) and the deteriorating terms of trade between rural products and urban consumer goods. The price of fertiliser has risen dramatically in comparison with that of oranges and particularly that of maize. Commercial farmers in other parts of the country have long abandoned maize and beans as unprofitable and concentrated on animal feed or export crops. In the southeast, peasants continue to grow them because of tradition and because they form the basis of the family diet, thus allowing them to partially feed themselves. However, it is doubtful how many of the young people are willing to maintain the tradition under present circumstances. They often prefer to look for work as brick layers in the construction industry where their career prospects are slightly better.

Maize has been the focus of much APB research in DCs (Vasil, 1988) and in the Centro Internacional de Mejoramiento de Maiz y Trigo (CIMMYT) and has already been successfully transformed genetically (Rhodes et al., 1988). Nevertheless, all the efforts have been directed towards the production of improved seed for cultivation under intensive large-scale agricultural systems such as in the United States. As far as we can judge, small-scale subsistence agriculture, as practised in the southeast of Mexico, is of little interest to them. Their seed will be patented, more expensive and inadequate for poor ecological and technological conditions. On the other hand, even if Mexican APB research on maize were to successfully produce new more suitable varieties, the majority of farmers would not have the capital to adopt them and the low guarantee price would not cover the cost of more expensive inputs. It is doubtful however that varieties will be made available in the short term specifically for the low-resource agriculture of the southeast. Thus, ironically, although maize is the most important Mexican food crop in the region, it is one of the least likely to benefit from APB.

ANALYSIS OF SELECTED CROPS

Citrus in Yucatan

Since the decline of the henequen industry, which reached its peak at the beginning of the century, Yucatan has been searching for viable alternatives with which to diversify its economy. Citrus is one of the few crops which grows relatively well in the unfavourable ecological conditions of the region. Its cultivation has recently led to a successful agro-industry within the ejidal sector. The application of APB to it is economically feasible and the region's previous experience with new technology gives some indication of what results can be expected from the use of APB.

Yucatan is a karst plateau with no surface drainage and extremely thin, calcareous soils spread over all but the southern Puuc region. Rainfall is the single most important factor determining the success of agriculture but the probability of it achieving the mean in any one month is very low (Ewell, 1984). The late arrival of the rains can spell disaster for the harvest. Only in a small stretch in the south are ecological conditions slightly more favourable. In this stretch it has been possible to establish mechanised farming and intensive fruit and vegetable growing which allows the local population to gain reasonable income from agricultural activities as well as from sales to the nearby cities (Merida, Cancun, Chetumal, Campeche and Valladolid).

Although citrus fruit has formed part of the region's peasant production since the last century, it only became important in the 1960s when funds were made available for large-scale agricultural projects (implemented through the ejidos) in an attempt to diversify Yucatan's agriculture. One of the largest schemes was "Plan Chac" (the Rain God Plan), designed to introduce citrus production based on GR technology. It illustrates some of the social and environmental problems which have made the implementation of agricultural modernisation so difficult in the southeast.

Funds for Plan Chac (four million dollars, from the Interamerican Development Bank and the Federal Government) and organisation through the state authorities were provided for the project infrastructure to develop an area of around 4,000 hectares. Sophisticated Israeli equipment was brought and installed for joint user operation; SARH technicians were sent to Israel for training; budwood was introduced from California, demonstration plots were set up and Banrural supplied credits to the ejidos to cover the living and operation costs of the 1,600 peasant families involved while waiting for the plantations to grow.

Although many deficiencies (such as untimely and inadequate credit, insufficient inputs, etc.) were apparent in the project's operation, the main problem, which only became noticeable five to 10 years later, was the incapacity of the local market to absorb all the oranges. In the absence of adequate infrastructure for exportation, the effect of the project was to flood the local orange market, bring the price to even lower levels than before and force many of the producers (who preferred to leave their oranges to rot on the ground than take them to market at a loss) to look for alternative work. When Ewell carried out his study of the region in 1980-81 (Ewell, 1984) he found that only half the projected area had been brought into production at an average capital cost of \$2,000 per hectare, that the irrigation equipment was lying unrepaired and that very little of the original credit had been repaid. In addition, the orange plantations had been severely neglected and were only giving yields of around eight tonnes per hectare (as compared to 40 in Florida). Government officials accused the orange growers of laziness and irresponsibility while the growers pointed to the fact that SARH invariably failed to repair the irrigation equipment on time so that two or three weeks might go by without being able to irrigate certain plots. Moreover, the credit and chemical inputs (deducted at source from the credits provided by Banrural) were insufficient and often arrived late.

By 1988 the situation was dramatically different, however. The changes began around 1983 and within a matter of four years the citrus project changed from being considered a financial failure to a rare success. The price of oranges is now high (see Table 2), the farmers with grown plantations are reaping profits. The price of irrigated land (whether ejidal or private property) is rocketing. The reason, however, is not directly linked to the technological innovation (as can be seen from the long time lag between the adoption of GR technology and the improvement in economic indicators) but to market forces. This serves as a reminder of how dependent new technologies are on economic circumstances, however promising their potential.

The increased demand and price of oranges can be traced almost entirely to the construction of a concentrated orange juice plant in Akil towards the end of the 1970s. It was built with a loan from the Federal Government, after years of pressure from the Union of Orange Growers who complained that Plan Chac was yet another example of state-funded failures in the region. The loan was given to the Union which became the legal owner of the plant. It is run

Table 2

Quantity and price of oranges processed by the Akil Plant (1981-1988)

Year	Tons Processed	Price (pesos/ ton)	Profits distributed to Union members (pesos/ton)
1981-82	11,629	3,000	-
1982-83	520	4,500	1,500
1983-84	20,035	7,500	2,000
1984-85	10,564	13,000	1,500
1985-86	32,498	23,000 25,000	500
1986-87	9,295	26,000	4,000
1987-88	20,995	60,000 100,000	8,000
1988-89		250,000	

Source: Akil juice processing plant, 1988.

collectively by an administrative council elected from the Union members. Today, the citrus agro-industry is considered one of the few successful agricultural development projects within the ejidal structure in Yucatan. Ninety per cent of the plant's concentrated juice is grade A and sold at an excellent price on the US market. It is amongst the highest-quality juices sent from Mexico and is superior to its rival product from Brazil. The plant operates with short-term credits from Banrural but always finishes the season with substantial profits. Some of these profits are redistributed amongst the Union members, the rest being reinvested in new equipment. In 1987, the plant more than doubled its processing capacity (from 250 to 600 tons of fresh fruit per day) by installing a second evaporator, a cooling tower, another boiling tank and equipment for washing fruit, jointly worth some US\$430,000.

At present the plant only works six months a year (September to February) which is when oranges of the right quality are available. After February there is almost no orange production until July when the so-called "early varieties" begin to ripen. No other region in Mexico manages to produce them so early, which accounts for the very high prices the Yucatecan growers can command for fresh fruit during July and August. The oranges are not ripe enough for processing at this time and the growers are keen to reap the higher prices paid by intermediaries from other parts of Mexico, but they risk leaving the factory without sufficient raw material. It is generally recognised by the orange producers that they would benefit by intensifying production and prolonging the season of ripe oranges which could be achieved by planting different varieties.

Production problems

For all its relative success, there are a number of production problems which require solutions if the citrus industry is to continue to grow and provide an increasing number of jobs for the local population. In spite of the fact that Yucatan has certain geographical advantages as an orange producer: a large amount of insolation, high temperatures and small diurnal variations which would appear to be the main causal factors in the high juice and sugar contents of the fruit. They also contribute to the early maturation of the oranges. The region also faces some serious disadvantages: low soil nutrients, water deficiency, the prevalence of pests and diseases and, as has been mentioned above, the concentration of fruit production into six months of the year, leaving the juice plant idle for the rest of the time.

As can be seen from Table 3 the most crucial factor for orange production in the Puuc region is irrigation. According to SARH's most recent figures, the average irrigated yield without fertiliser is 16.3 tonnes per hectare while the equivalent rainfed yield is as low as 6.8 tonnes per hectare. On the other hand, apparently fertiliser only increases yields marginally (10 per cent) bringing the average irrigated yield up to 18 tonnes per hectare. However, this small difference is probably more a reflection of poor fertiliser application (particularly low amounts) than of the importance of adding nutrients to the soil. Where irrigation is not available (only 3.4 per cent of the land planted with oranges) it is not even worthwhile for the producers to use fertiliser.

Yucatan's orange yields compare very unfavourably with those of Florida (40 tonnes per hectare) which gives an indication of the magnitude of the losses due to poor management and severe environment. It is calculated that pests and diseases are collectively responsible for reducing yields by as much as 50 per cent. The Mexican fruit fly is the most damaging pest and can only be controlled with the frequent application of chemicals (SARH recommends malathion applied every 20 days after flowering) which is expensive and a health hazard for those who spray it.

Table 3

A: Irrigated orange production in the Puuc region

P L A N T E D A R E A (H A)				H A R V E S T E D A R E A (H A)		
ESTABLISHED	NEWLY PLANTED	YOUNG PLANTATIONS	TOTAL	WITH FERTILIZER	WITHOUT FERTILIZER	TOTAL
4,748.5	13.5	1,068.5	5,830.5	1,754	1,926	3,680

P L A N T E D A R E A		TOTAL PRODUCTION	Y I E L D	
		(T O N S)	(T O N S / H A)	
WITH CREDIT	WITHOUT CREDIT		WITH FERTILIZER	WITHOUT FERTILIZER
696	4,051	62,798	18.0	16.3

B: Rainfed orange production in the Puuc region

P L A N T E D A R E A (H A)				H A R V E S T E D A R E A (H A)		
ESTABLISHED	NEWLY PLANTED	YOUNG PLANTATIONS	TOTAL	WITH FERTILIZER	WITHOUT FERTILIZER	TOTAL
198	0	0	198	0	198	192

P L A N T E D A R E A		TOTAL PRODUCTION	Y I E L D	
		(T O N S)	(T O N S / H A)	
WITH CREDIT	WITHOUT CREDIT		WITH FERTILIZER	WITHOUT FERTILIZER
0	198	1,346	-	6.8

SOURCE: UNPUBLISHED DATA FROM SARH'S CENTRE FOR RURAL DEVELOPMENT SUPPORT, NO.2, 1987.

In spite of the general awareness of the benefits to be derived from the use of better-quality genetic material, more fertilisers, and the chemical control of pests and diseases and its cost effectiveness, the application of this knowledge is sometimes impeded by the lack of cash at a particular moment and insufficient technical information. Relatively few orange producers (12.6 per cent in the south) have credits from Banrural, and depend predominantly on their own resources which fluctuate greatly over the year. A severe illness or bad harvest can restrict their capacity to purchase inputs or pay day labourers at the right time and this is then reflected in poor yields (see Table 4 for an estimation of production costs). In addition, SARH technical assistance has been very deficient due to poorly-trained staff and inadequate resources to visit all the producers.

Little is known about viral diseases in the region the effects of which are not always visible. This has led some people to conclude that viruses are not a problem. However, experts from other parts of the country consider it likely that they are present and diminish yields since no selection or programme to plant virus-free trees has ever been implemented. Indeed, no one is even sure which citrus varieties are planted as the original budwood was brought into the region last century from all over the world by hacienda owners and has since been continuously propagated without control. All that is known is that the majority are "early" producers, conferring on Yucatan its advantage over other regions but also concentrating the production into a few months of the year. Before APB can be applied, it is clear that a study is required of the available germplasm in the region to characterise the genetic traits of each variety as well as a screening programme for viral diseases. The Union of Orange Growers has talked about sponsoring such a project and of the need to plan new plantations in a more systematic way but at present it does not have the funds. However, the union leaders, who are also some of the more innovative producers, are encouraging everyone to plant late varieties to fill the production gap.

Employment and income from citrus

According to SARH's latest statistics there are at least 5,246 orange producers in the Puuc region, the overwhelming majority of whom are small (97.7 per cent, see Table 5), i.e. work less than three hectares. It is normal for the small peasant producers to follow a low-risk strategy of combining agricultural activities (staple food for consumption with perennials which represent long-term investment and relatively little labour and annuals such as chilis, water melon and tomatoes which permit a rapid turnover of capital) so that oranges are never grown as a monoculture. The producers probably spend less than a third of their time on citrus. Some growers manage to combine a fixed job with cultivating their plot of land often with the help of family labour or by hiring day workers when necessary.

As can be seen from Table 6, the majority of the producers (76.2 per cent) have ejidal rights to land but have access to only very small irrigated plots (1.7 hectares on average), the rest of the land being rainfed and used for maize and beans (they invariably have rights to a total of four hectares). Citrus cannot be successfully grown without irrigation as can be seen from the figures on yields. Although not visible from the statistics many of the ejidatarios also have private property. Small property owners (who are not simultaneously ejidatarios) form a minority of the producers (only 23.8 per cent) and have on average even smaller parcels of land (0.5 hectares each). There are, however, marked differences in the size of private properties and verbal reports suggest that private land is concentrated into relatively few hands although none can be called large farmers by DC standards. About 23 producers have more than 10 hectares and of these, two have more than 50 hectares.

Table 4

Citrus production costs in the Puuc region
(Thousands of pesos per hectare per year in 1988 prices)

Work activity	Establishment of plantation			Year 1			Year 5			Year 9		
	Labour	Inputs	Total	Labour	Inputs	Total	Labour	Inputs	Total	Labour	Inputs	Total
Preparation of ground	1,400	-	1,400	38		38						
Planting	140	224	364	21	22	43						
Application of fertilizer and manure	21	40	61	70	40	110	105	40	145	105	40	145
Weeding and pruning	210	-	210	280		280	280		280	280		280
Irrigation	175	147	322	476	180	656	560	180	740	560	180	740
Disease and pest control	70	30	100	210	60	270	210	60	270	210	60	270
Harvesting and transport	-	-	-				70		70	105		105
Total	2,016	441	2,457	1,095	302	1,397	1,225	280	1,505	1,260	280	1,540

Source: Producer interviews, 1988.

There are no accurate data for the number of day workers but based on SARH's estimates, the figure cannot be below 3,052, (see Table 5). Most of them will spend at least some time on oranges, it being the predominant cash crop of the region.

In addition, approximately 21 industrial workers are employed by the Union of Orange Growers in the concentrated juice plant (personal communication) while around 11 men are full time lorry drivers and some 34 market vendors. Observation on several market days suggests that there are frequently as many as 30 people carrying produce around for clients. Thus, in total citrus provides employment for some 8,406 people or about 37.4 per cent of the EAP in the Puuc region. These figures no doubt underestimate the real numbers, however.

Although it is too early to be reflected in the official statistics, the Akil juice processing plant has generated demand for field labour and real incomes to rise significantly. Day workers are hard to find and will often not work unless they are offered more than the minimum wage. The large producers who require permanent workers are obliged to give them extra benefits in order to keep them from looking for alternative work. Another indication of the high demand for labour is the abundance of employment "hookers" who play an important role putting day workers in contact with employers. Since hurricane "Gilbert" destroyed large areas of maize in different parts of Yucatan in September 1988, peasants have migrated to the Puuc area (which suffered very little) in search of work and have been easily absorbed into the regional agricultural workforce.

At the same time there has been an increase in informal service jobs related to agriculture, particularly in and around the market which opens every day of the week. Transporters with tricycles abound and have no shortage of well-paid work and even manual carriers can earn twice the minimum wage on busy market days. Women vendors monopolise the commercialisation of fresh vegetables and fruit in the market place, buying from wholesalers and reselling at a comfortable profit if they have no produce of their own. Young children can also earn tidy sums by helping relatives with their stalls or transporting products for clients.

The multiplier effect of the Akil plant has been such that a reversal in relative incomes of agricultural producers and petty bureaucrats has taken place. Eight years ago it was prestigious and economically rewarding for men to get jobs in SARH and some producers even abandoned their plots in favour of a steady job in the government. However, since the crisis began in 1982, lower government officials' salaries have not kept pace with inflation so that in real terms they earn very little now. On the other hand, the producers who managed to hold on to their 3 hectare plots of land originally granted under the Plan Chac scheme and other similar ones through the difficult years, can earn two or three times the annual salary of a petty bureaucrat and without the limitations of an office routine. Many government employees wish they had parcels of irrigated land to work, but land prices, even ejidal land which cannot legally be bought or sold (although it does change hands frequently by compensating the previous owner for the improvements made to the land) have risen so much that few can aspire to save enough to buy even a small plot. Not more than four years ago no one was even interested in buying agricultural land in the region.

These relative changes in incomes and land prices have provoked considerable upward social mobility. In 1970, according to Webber (1980), the class structure of Yucatan was in the order of: 1.4 per cent constituting the upper class, 16.2 per cent the middle and 82.4 per cent the lower (see Table 7). Using the same criteria we estimated the class structure of the citrus

Table 5

Citrus and employment in the Puuc region

Type of employment in agricultural sector	Number of jobs	%
Small producers (< 3 ha)	5,123	97.7
Medium producers (3-10 ha)	100	1.9
Large producers (> 10 ha)	23	0.4
Total producers	5,246	62.4
Farm overseers	12	0.1
Agricultural day workers	3,052	36.3
Employees in juice plant	21	0.3
Lorry drivers	11	0.1
Market vendors	34	0.4
Carriers	30	0.4
TOTAL	8,406	100

Sources: Adapted from SARH, Centre for Rural
Development Support No. 2 unpublished
Citrus production data 1987, and producer
interviews in Oxxutzcab, 1987.

Table 6

Type of orange producer and access to land in the Puuc region

TOTAL NUMBER OF PRODUCERS	EJIDAL	%	AVERAGE IRRIGATED AREA PER PRODUCER (HA)	SMALLHOLDERS	%	AVERAGE IRRIGATED AREA PER PRODUCER (HA)
5,246	3,998	76.2	1.7	1,248	23.8	0.5

SOURCE: UNPUBLISHED DATA FROM SARH'S CENTRE FOR RURAL DEVELOPMENT SUPPORT, NO 2, 1987.

zone from the 1980 census data. As shown in Table 7, it has a markedly more skewed distribution amongst the classes with 95 per cent of the population falling into the lower class (if one includes the unspecified and unemployed) and only 4.7 per cent and 0.3 per cent in the middle and upper classes respectively. The latter is composed of no more than a handful of business families some of whom also have prominent roles in the local government. However, this simplified classification is based largely on occupation status and does not consider salary. Although there are no census data to bear this out, our survey of producers suggests that as many as 6,000 (or 34 per cent) of them are fairly well off now due to the impact of the juice plant, and constitute an upper lower or middle class of entrepreneurial peasants. While it is undeniable that the gap between the richest and the poorest in the area has increased, it is important to note the relatively large proportion of better-off producers (over 30 per cent) and the fact that the generally healthy state of the local economy has raised the employment and income opportunities for a large number of those who do not have access to irrigated land.

However, it is unlikely that the same rate of upward mobility can continue for long due to the restricted availability of irrigated land. It would appear, in fact, that the limits of the redistributive agrarian reform structures have been reached and that from now on there will be a tendency for land to accumulate again in relatively few hands and for marked social and economic differentiation to take place.

State of the art: APB

Contrary to the situation in the other crops that we discuss here, an enormous amount of work has been done on Citrus tissue culture and there is great scope for applying these techniques to improve citrus trees [for general reviews see Navarro and Juárez 1977, Spiegel-Roy and Vardi (1984) and Barlass and Skene (1986)]. There are two main ways in which PTC can contribute to Citrus production. The first one, of immediate use, is through the production of disease-free stocks. The second is the production of new mutant or hybrid varieties through somaclonal variation or protoplast fusion.

Citrus viruses are rarely transmitted by seed (the exception being psorosis) and budding, which is the standard propagation method. It is also the main route of dissemination of this disease. Although insect vectors also play a role in dissemination, this is a much slower process and can be controlled by eliminating the vector or the source of disease. There is no way to control the spread through budwood. In Citrus, virus-free plants can be produced by one of two methods which are described below.

Nucellus and ovule culture: Viruses in citrus are restricted to the phloem and since there is no vascular connection between the somatic and the reproductive tissues, the nucellus or the ovules can be cultured in vitro to give rise to adventitious embryos which are free of viruses and, at least in theory, are genetically identical to the mother plant.

Navarro and collaborators (1985) found that all plants regenerated from ovule culture in polyembryonic cultivars are true to type but they also found that 29 per cent of the 165 plants regenerated from nucellar embryos in monoembryonic cultivars showed abnormal phenotypic characters that were maintained through budwood propagation on different rootstocks. All the trees derived from somatic embryos presented juvenile traits; they are vigorous and thorny and have to wait for many years before they can be acceptable for commercial propagation.

Table 7

Changes in class structure in the Citrus Zone: 1970 to 1980

Occupation	Class	Percentage of total occupations	
		1970 ^a	1980 ^b
Public officials, managers, administrators, proprietors in private sector	Upper	1.4	0.3
Professionals and technical workers, administrative personnel, businessmen	Middle	16.2	4.7
Personal service workers, transport workers, agricultural producers, cattlemen, lumbermen, fishermen, hunters, non-agricultural workers, machine operators	Lower	82.4	78.0
Unspecified and unemployed	lower	-	17.0
TOTAL		100.00	100.00

a Source: Webber, 1980 and it relates to Yucatan state.

b Source: SPP, INEGI, 1983, relates to the Citrus Zone.

Shoot tip grafting: The difficulty to culture isolated citrus meristems led to the micrografting technique developed in Murashige's Laboratory and perfected by Navarro (for review see Navarro and Juárez 1977). This technique consists of the isolation of meristems from scion plants and its grafting, under asceptic conditions, on a decapitated rootstock seedling germinated in a test tube. The leaves and fruits of all plants obtained through this technique are identical to those of the mother plant and, most important, do not revert to the juvenile state as do plants formed from nucellar embryos. Micrografted plants are ready for budwood increase in two to three years.

Micrografting produces plants free of: tristeza, seedling yellows, psorosis A and B, concave gumm, infectious variegation, vein enation, direct mottle, yellow vein, cachexia, stubborn and exocortis. The last five are very difficult to eliminate by thermotherapy.

Micrografting constitutes the basis of the citrus variety improvement programme in Spain (Navarro et al., 1981), aimed to produce disease-free plants from all varieties grown in Spain or elsewhere that might be useful to improve production. All plants produced in citrus nurseries in Spain are virus free and growers can be sure in this way that the materials they are planting are of the highest quality.

An additional method to propagate healthy plants in vitro would be very useful. Barlass and Skene, 1986 have attempted a combined strategy of virus elimination and multiplication via adventitious or axillary shoots formed on stem nodes or internodes. Young seedlings have been used as a source of explants because of their regenerative competence and because having nucellar origin should be genetically identical to the mother plant and therefore their superior characteristics are known. Nevertheless, as in the case of nucellar embryos genetic differences also occur in seed-derived seedlings and no information regarding the efficiency of the system is provided.

Many varieties of Citrus are polyembryonic: this means that the fertilised zygotic embryo causes the nucellus around the ovule to generate somatic embryos which in turn suppress the development of the former. In consequence, seeds contain more than one embryo of somatic origin and only occasionally some of hybrid origin (Button and Koshba, 1977). This situation complicates the selection of hybrid seedlings from controlled pollination. On the other hand, some of these cultivars have very few or no viable seeds at all, preventing their use as maternal parents. However, the variations present in nucellar embryos further increased by mutagenic treatments can become an important source of new traits.

In the long run tissue culture will undoubtedly have an impact on the production of new traits. Salt-tolerant citrus embryos have been selected in vitro by Koshba and collaborators (1982) but it is still not certain that the mature plants will retain this tolerance. Mutagenesis and in vitro selection for disease resistance has not been attempted. Resistance to viral diseases could be introduced through recombinant DNA techniques by means of genes that express the virus coat protein or its antisense RNA chains that can neutralise the expression of viral genomes as it has been done for tobacco mosaic virus (Nelson et al., 1988) and cucumber mosaic virus (Cuozzo et al., 1988). It has been argued that cross protection systems, such as the one employed in Brazil for the control of tristeza, are cheaper and more efficient. However, the hazards associated with the introduction of viruses in the fields must be borne in mind.

Protoplasts fusion also seems to hold promise in this area and somatic hybrids of sexually compatible Citrus sinensis + Poncirus trifoliata and between sexually incompatible C. sinensis + C. unshiu (Satsuma mandarin) have been produced (Kobayashi et al., 1988).

A recent paper (Marin and Duran-Vila, 1988) reports a successful method to preserve somatic embryos of Washington navel sweet orange derived from in vitro cultured ovules. About 4 per cent of the embryos stored at liquid nitrogen temperature survived and developed into cultures that produce whole plants that are growing successfully. A tissue culture system for the conservation of Citrus germplasm is important since commercial citrus cultivars are propagated through grafting on rootstocks and the seeds, although not strictly recalcitrant, do not remain viable for extended periods under dry storage conditions.

In vitro culture of juice vesicles from Citrus fruits has been attempted by some workers (Einset, 1978; Tisserat and Gallella, 1987) and has received some attention as a technique that might lead to the production of natural fruit juice in large-scale fermentors (Business Week, 17 November 1986). The production of any substance in a large-scale bioreactor is a very attractive possibility since it would be free of all the problems that accompany crop production, i.e. pests and unfavourable environmental conditions, such as drought or frost. Other economic advantages would be that processing might not be necessary and transportation from distant places would be eliminated

with the extra bonus of creating jobs instead of importing a product. Furthermore, the developed countries could decrease their dependence on politically unstable developing countries.

The attractiveness of such industrial production over traditional agricultural methods should not be under-estimated. If these new methods were to become economically viable they could represent a very serious threat to growers. However, at least in the case of Citrus this seems to be a very long-term possibility since the techniques (at least the ones reported in the scientific press) are riddled with problems to induce growth and multiplication without losing the differentiated state of the juice vesicle. New approaches to culture techniques will have to be developed before orange or lemon juice can be escalated economically from the laboratory into large-scale bioreactors.

Socioeconomic impact

Most of the citrus industry worldwide is nowadays based on nucellar lines from old clones that are physiologically rejuvenated. To what extent the greater vigour, longer lifespan and higher yield shown by these new lines is due to the fact that they are largely, if not entirely, free from virus diseases is not known.

This prevention of disease might be the most important contribution of tissue culture and as such its benefits will be difficult to quantify. Tissue culture techniques are ready to be applied to citrus production programmes as the citrus variety improvement programmes in Spain and similar others in the United States, Israel and France clearly demonstrate. In Mexico, a programme to produce certified virus-free stocks of citrus (oranges, lemons, grapefruit, tangerine and root stocks) is being carried out by Universidad Autonoma de Nuevo Leon in collaboration with INIFAP. So far, 114 cultivars from different sources have been processed through thermotherapy and micrografting and the plants were indexed on indicator plants (Lozoya-Saldaña, personal communication). However, this programme is hindered by insufficient resources and it is unfortunate that their participation in a Latin American effort of collaboration on similar lines between Argentina, Colombia, Costa Rica, Cuba, Mexico and Peru did not receive the support of the "Programa Regional de Biotecnología UNDP/UNESCO/UNIDO para America Latina" in spite of the fact that the project was positively evaluated by the referees.

The application of APB to produce virus-free citrus material in Yucatan could have beneficial effects on productivity at a relatively low cost. It would imply the setting up of a basic laboratory with a few trained staff and the green house facilities to produce 500,000 plants per year (the number that is presently sold in the region). At the moment, growers buy their scions grafted on sour orange from CONAFRUT (at 50 cents US per plant) and from the Akil factory (at 40 cents US) but have no guarantee of the quality. Although it is difficult to estimate the costs of improved material, more than half the growers said they would have the means and would be interested to buy it if it paid off economically. This suggests that there is a market to be tapped but that the initial investment to set up the laboratory and train the technicians is missing. CONAFRUT should be responsible for such programmes but, unfortunately, it is severely underfunded and understaffed. It is barely able to finance the few soil, leaf and water tests it carries out for the growers and the maintenance of its phenological orchard.

CICY is the only research institution in the southeast with the capability to scale up plant biotechnologies and is currently building a pilot micropropagation laboratory for large-scale production to study and facilitate

the transference of this technology. Since neither CONAFRUT nor the Union of Orange Growers is in a position to invest in their own commercial laboratory and there is no interest from private companies, the only possibility of applying the technology would be through an inter-institutional collaboration between CICY, CONAFRUT and the Union. If the industry continues to grow, the Union will soon feel the need to improve its production. In fact, it has already taken steps to do so by hiring its own better-qualified agronomists (rather than depend on SARH's technical assistance) and by forming its own credit union.

Although adopting APB for oranges in Yucatan does not represent saving a crop for small farmers, as in the case of coffee, nor does it, in fact, imply solving what is currently believed to be the main cause of citrus losses (the Mexican fruit fly), it does pose the possibility of intensifying production, enhancing growers' incomes, providing more work for day labourers, bringing the juice processing plant into full production all year round (and therefore slightly increasing the number of industrial jobs) and stimulating the local economy. So long as the local market for fresh fruit and the US market for frozen concentrated juice hold, it would stimulate economic growth whose impact on the region would probably differ little in quality from that produced by the application of GR technology once the Akil plant had been built. APB alone, however, cannot be expected to create a massive number of jobs for new growers (which depends primarily on the government providing more irrigated land) and, therefore, to the degree that the availability of more wells does not satisfy demand, APB would accelerate the process of social differentiation in the area.

As long as the application of APB is restricted to citrus in Yucatan (as seems probable in the short term) it will not directly contribute to alleviating the plight of poor consumers and improving health and nutrition. Indirectly, however, the economic growth in the local economy could have some small, positive trickle-down effects.

Henequen

Henequen (Agave fourcroydes Lem), a hard fibre-producing agave has, together with maize, been the most important crop in Yucatan for the past 100 years or so. It constituted the basis of the region's wealth during the first part of the century but was slowly driven out of the international market, first by competition from sisal (a close relative that was taken from Yucatan to Tanzania by the English) and later by synthetic fibres. The history of henequen has been very well documented as an example of a flourishing monoculture agro-industry dependent on a foreign market which suddenly collapsed, leaving a devastating social problem behind, which still lingers on more than half a century later (Benitez, 1956).

Nowadays the crop is cultivated only in Yucatan and the fibre is industrialised mainly by CORDEMEX, a parastatal industry that manufactures ropes and twine and employs about 5,600 people.

The future of this agro-industry has been hotly debated since many people think it should be replaced by other crops. Given that in 1980, the production of henequen represented 18.3 per cent of the volume of the agricultural production of Yucatan and, in spite of its low price, 48.3 per cent of the total value, this appears to be an impossible task.

It is difficult to calculate the number of people who depend on henequen for their subsistence because of the inaccuracy of the records, the

complicated system by which the state "pays" the henequen ejidatarios (discussed below) and the drastic changes that the industry has suffered over the past 40 years. However, in 1981 the number of henequen field workers ("henequeneros"), including ejidatarios and small property owners, was estimated at 69,460, that represented 60 per cent of the state's agricultural EAP (see Table 19). On the other hand, the number of people employed in the henequen textile industry was 12,500 making a total of approximately 82,000 people or 22.3 per cent of the total EAP in 1980 (Lopez Huebe and Garcia de Fuentes, 1984).

Henequen production has decreased considerably during the last 10 years: in 1978 around 80,000 tonnes were produced whereas this year, according to FAAPY, it is expected to reach only 36,000 tonnes. Ironically, therefore CORDEMEX now has to import 12,000 tons of sisal fibre per year from Brazil (or 25 per cent of the fibre it processes) to make up for the insufficiency of the local plantations.

Although the reasons for the low productivity are too many, and too complex, it is important to mention three points: 1) the low price that the natural fibre fetches on the world market; 2) the long time period of government authoritarianism, exploitation and paternalism towards the henequen ejidatarios which has produced a sense of apathy and hopelessness in many of them (Baños, 1988); and 3) the absence of any economic incentive to improve efficiency. The ejidatarios receive a "credit" payment from the government, supposedly in remuneration for the agricultural tasks carried out on the henequen plantations. However, this never amounts to more than US\$15 every two weeks (a third of the minimum wages) which, in terms of purchasing power, represents little more than three kilos of meat. In partial recognition of its inadequacy, even as a subsistence income and because of the large numbers of henequen workers, the government pays this "credit" (which it knows it will never fully recuperate through henequen production) to the ejidatarios even if they do not carry out their tasks satisfactorily. It is evident that the henequen workers cannot live on their state credit alone and have to look for additional sources of income which leads them to seriously neglect the plantations.

But, even if economic circumstances were to change dramatically, there is another reason why it will be difficult, costly and slow to renovate the henequen industry: a shortage of plantlets with which to replant the fields.

In 1984 a government programme to reorganise the henequen zone: the Programa de Reordenación Henequenera y Desarrollo Industrial de Yucatan (1984), determined that 63,000 new hectares should be planted by 1990 to cover the immediate needs of CORDEMEX. However, this will not be achieved until at least 1994 because the plantation of 50 million plantlets in 500 hectares of nurseries is very much behind schedule. Although INIFAP has carried out a successful research programme on methods to increase the production of "hijuelos" (the reproductive off-shoots). This implies that the henequen workers adopt new practices which they so far have been reluctant to do.

Many attempts have been made in the past to diversify the uses of henequen in order to increase its value added. Composite building materials, converting it biotechnologically to unicellular protein, the use of its cellulose for paper production, are a few of the alternatives that have been considered (Cruz et al., 1985). More recently, the transformation of the sapogenins (present in large amounts in the wasted juices from the decortication process) into valuable steroids for the pharmaceutical industry, seems to be the most likely to succeed.

In the search for alternative uses it was proposed in the early 1980s that cellulose from henequen could not be used to produce paper and the establishment of a paper factory in Yucatan was seriously considered. To feed the plant with the nine million leaves/day required to keep it working at its full capacity, 135 million "hijuelos" had to be planted (Villalbaz et al., 1985). Although the figure needed is far too high even for the most efficient in vitro systems, micropropagation was suggested as an alternative way to speed up multiplication. The government abandoned the paper factory project but carried out the work on micropropagation.

State of the art: APB

From the work at CICY (Robert et al., 1987) it is known that Agave fourcroydes can be very efficiently multiplied in vitro from several tissues; shoot formation can be induced from subapical meristem tissue or from rhizome - derived callus. These shoots can multiply in vitro through the induction of four to five new adventitious shoots every four weeks.

A faster and even more efficient multiplication system is from the axillary buds in the rhizomes (Robert et al., in preparation). About 10 unignified meristems can be obtained from a young plant and then cultured in vitro to induce the formation of adventitious shoots. It is therefore theoretically possible to produce one million plants from a single mother plant in one year, a considerable improvement from the 12-14 that the same plant produces naturally in its entire life cycle. The performance of the micropropagated plants, that until now have been only evaluated under nursery conditions, might be an extra bonus to productivity: the plants grow 70 per cent faster than those from rhizomes, produce more leaves and give off rhizomes when they are only one year old (Robert et al., in preparation). However, in spite of the low costs of this method, the in vitro produced plant still cannot compete with the very low price of traditionally propagated ones, particularly if the cost of setting up a laboratory is considered. Although the in vitro production of several million plants is out of the question, micropropagation could contribute to multiply the initial number of plants needed to increase the plantations.

There is another aspect of the biology of henequen which makes in vitro propagation a suitable alternative: this agave has a very long life cycle (18-25 years to set flower), a high level of ploidy (pentaploid with 150 chromosomes) and inefficient sexual reproduction (very low seed viability). This, combined with the fact that flowers mature at different times at the top of a thin 5-8 metre tall inflorescence stalk, make it a very difficult species to breed for genetic improvement. Micropropagation could also make an important contribution within the framework of a long-term programme, to increase productivity through the cloning of elite individuals.

It is important to note that the knowledge obtained through working with henequen has been applied to a different agave (Agave tequilana) from which tequila is made in the State of Jalisco (Robert et al., unpublished results).

Socioeconomic impact of APB

In spite of its position as an industry in protracted decline, heavily subsidised by the state, henequen is crucial to Yucatan as a source of employment for 22.3 per cent of its total economically active population which consists of extremely low-paid fieldworkers. Its importance resides in the fact that during more than 50 years of searching for alternative employment opportunities, it has been impossible to find an adequate substitute. The citrus agro-industry, although promising and beginning to be developed in the henequen zone as well as in the south of the state, has so far only managed to provide jobs for around 16,000 people.

The application of APB to henequen is technically feasible; Yucatan has the research capability and it could have a positive impact on productivity and the availability of plantlets to increase the henequen plantations in accordance with the government programme. However, even if it is applied on a small scale, APB by itself will do little to increase the employment opportunities and the subsistence level living standards of the henequen workers who are trapped in a state-controlled production system where political interests override those of efficiency and economic welfare (Brannon and Baklanoff, 1987). APB could be a tool to renovate and maintain in a more healthy state an industry for which the international market is stable (Garia de Fuentes y De Sicilia, 1984). But without concomitant political and structural changes, the socioeconomic impact on the majority of people who depend on the crop, will be minimal. This contrasts markedly with the privately-owned, high-value tequila industry in Jalisco which has already begun applying APB and which stands to gain considerably from it.

Coffee

Coffee is Mexico's main agricultural export product, representing a fluctuating proportion of its agricultural exports ranging from 24 per cent to as much as 50 per cent. It is second only to oil in total value of all national exports. In 1986, Mexico exported 208,330 tonnes of coffee worth 877 million dollars (40 per cent of its agricultural revenues, FAO, 1987a). But although Mexico occupies fifth place in the world trade of coffee (after Brazil, Colombia, Cote d'Ivoire and Indonesia) its contribution is so small (5 per cent) that it exerts little or no influence on world supply. Nevertheless, unlike some coffee-producing countries, Mexico has a high internal demand (between 35 and 50 per cent of the production is consumed nationally) which makes it less susceptible to changes on the international market.

Coffee is planted on more than 500,000 hectares in 12 states of the country. Out of these Chiapas is the main producer with 146,770 hectares (29 per cent) planted in 1984 and a production of 79,000 tonnes, equivalent to 33 per cent of the country's production (SARH, 1984).

Employment and production systems

In terms of agricultural employment, coffee is also the single most important crop in the southeast. In some parts of Chiapas there is no alternative other than coffee growing for the campesinos who increasingly need to supplement their subsistence agriculture with some form of cash income. It is estimated (Nolasco, 1985) that about 400,000 people depend for their livelihood partially or totally on coffee production in Mexico (see Table 8). Of these, the largest and most impoverished group are the agricultural day labourers many of them from ethnic groups without access to land of their own and who work for the coffee producers. Some of them are migrants from poorer areas such as Guatemala while others are simultaneously small coffee producers themselves or subsistence-dependent campesinos but who are temporarily forced to sell their labour because of their precarious economic conditions. (This applies to about 30 per cent of the producers.)

Next in size is the group of about 120,000 coffee producers. Of these the overwhelming majority (87 per cent) are small scale with an average of 1.5 hectares each. But as a group they own only 35 per cent of the land planted with coffee and produce only 18 per cent of the harvest. They also tend to be from ethnic groups, have little or no working capital, a minimal amount of technical knowledge and have their plots of land in the most remote, mountainous and least-communicated areas rarely visited by the government

Table 8

Coffee and employment

Type	Number	%
Producers:		
small	93,090	24.3
large	13,910	3.6
total	107,000	27.9
Agricultural day labourers	270,000	70.4
Industrial employees	4,350	1.2
Small, medium and large businessmen, transporters, export agents and others	2,000	0.5
T O T A L	383,350	100.0

Source: Adapted from Nolasco, 1985.

agencies whose function it is to provide extension and credit. At the other extreme, 2.5 per cent of the producers own 29 per cent of the coffee land (having plantations of well over 100 hectares) and produce 28 per cent of the product.

In addition to those involved in the production of coffee in the field there is a small group (approximately 4,350 in 1975) employed in the coffee industry and even a smaller number in a variety of related activities such as transport, commerce and exporting.

Finally, it should not be overlooked that for the majority of coffee producers, the unit of production is the family. Therefore much of the labour is contributed by unpaid members who are not registered in the official statistics. It is calculated that at least 66 per cent of the producers depend on their close relatives (mostly wives and children) to help, particularly at times of peak labour demand (Nolasco, 1985).

Not surprisingly, only the large, capital-rich producers can afford to make use of GR technology and consequently they achieve almost double the yields of the small producers (16.6 sacks per hectare as opposed to 9.3). (Nolasco, p. 206.) In addition, they have ready access to government and private credit and extension services while many of the small ones do not have any credit at all (26 per cent of all producers) or if they do, it is obtained under very unfavourable conditions. Finally, the large producers have well-established commercial contacts both in Mexico and abroad which allows them to obtain better prices.

The creation of INMECAFE, the state-owned coffee regulatory organisation, has had an important effect on the coffee industry (Villaseñor, 1987). It has not only improved agricultural practices but has also played a role in stabilising prices and, to some extent, has mitigated the disproportionate power of a minority of large plantation owners over coffee production. However, it has not been sufficient to allow the majority of small producers to significantly improve their production and hence their living conditions. Their main problems, due in large measure to their shortage of resources, are: 1) low yields; 2) ageing plantations; and 3) the high incidence of diseases, amongst which orange leaf rust, caused by the fungus Hemileia vastatrix is the most devastating.

Orange leaf rust disease

Mexico is particularly affected by this disease because the climatic and ecological conditions created by the shade cultivation system are ideal for the development of the fungus and because nearly 100 per cent of the shrubs are varieties of C. arabica which is extremely susceptible to it.

Leaf rust was detected for the first time in the state of Chiapas in 1981 and by 1984 it had attacked more than 100,000 hectares. It already affects more than 90 per cent of the small plantations and an unknown percentage of the large ones. The disease cannot be eradicated but can be satisfactorily held in abeyance with the application of cupric and systemic fungicides. However, the cost and lack of technical knowledge of the small producers put chemical control beyond their reach. Only producers with yields above 14 sacks per hectare can afford the expense which is estimated to be equivalent to two tonnes of coffee berries (this includes the cost of labour but not that of the spraying equipment).

Once the disease causes yields to fall below the already marginal 9.3 sacks per hectare, the producers who cannot afford chemical control are forced to abandon the crop. This could mean that, in the absence of a massive

intervention by INMECAFE providing free chemical control or credit for it, 75 per cent of the coffee producers might find themselves without the crop they have come to depend on so heavily for their cash income and sometimes for their entire livelihood.

In the long run, the application of APB could offer a cheaper and certainly more environmentally-sound alternative to the chemical control of leaf rust in coffee through the micropropagation of resistant varieties.

State of the art APB

Coffee varieties can be successfully cultured in vitro through a range of techniques (for a detailed review see Sondahl et al., 1984).

Direct (low frequency) and indirect (high frequency) somatic embryogenesis has been obtained in secondary cultures of mature leaves, cotyledons and hypocotyl tissues of many Coffea arabica cultivars. However, this is a slow process that takes more than eight months and has the disadvantage that embryos derive from callus and the genetic stability of the plants has to be carefully checked (Sondahl et al., 1984).

For vegetative propagation purposes axillary bud culture seems to be the most adequate technique since it ensures genetic stability of the clonal lines. About 415 shoots can be produced in one year from each orthotropic branch in 12 months; since each plant possesses several branches a large number of clones can be produced from a single mother plant. Sondahl and collaborators (1984) suggest this method could be used to propagate sterile interspecific hybrids and breeding lines for breeding programmes as well as for the commercial production of superior mother plants. This could be used to increase resistant genotypes to leaf rust.

Although Coffea arabica cultivars are derived from a very narrow genetic reservoir, high-yielding lines have been successfully produced through traditional breeding programmes. However, until now cross hybridisation has produced very little in terms of the urgently-needed resistance to pathogens and pests. Plant tissue culture techniques could offer new opportunities to solve this problem (until now only the low-yielding catimore progenies were available). After several unsuccessful attempts, somatic embryos and plants have now been obtained from protoplasts of Coffea canephora (Schopke et al., 1987). The breakthrough seems to be due to protoplasts derived from tissues with high regenerative capacity (zygotic embryos). This work could open the way to the production of new hybrids between C. arabica and C. canephora through protoplast fusion.

Other approaches to generate genetic diversity can be derived from the culture of macro and microspores. Chromosomal doubling of the haploids by chemical treatment would give homozygous lines for the screening of gametoclonal variants. Mutagenised secondary embryos and meristems could also be screened for resistance to disease.

APB can make an important contribution to coffee production in Mexico mainly in the control of orange leaf rust by producing the resistant materials through micropropagation. A very important aspect is that the country has the capacity to develop and exploit the technology. A collaborative programme between the Autonomous University of Chapingo, INMECAFE and SARH claims to have developed an efficient protocol for the clonal multiplication of some varieties of C. arabica (Madrigal Lugo and Bailón, 1987). Field trials carried out with the micropropagated plants show that the latter are comparable in morphology, productivity and quality of the grain to the seed propagated plants.

It is important to note that the methodology has something to offer the whole range of producers. For the small and medium sized ones the programme offers stocks of catimora F5 and F6 which are 100 per cent resistant to leaf rust disease and therefore do not require chemical control but have the disadvantage of being low yielding (5 to 6.5 kg of berries per tree per year). For the large producer, on the other hand, the programme could supply the high-yielding (18-20 kg per tree per year) Garnica variety which is susceptible to leaf rust but, because of its greater productivity, it more than compensates for the expense of chemical control. Due to the key role of INMECAFE in this programme of financial support, the government should be able to ensure that the clonal materials reach the small producers at a low price.

In the long term APB could contribute to the production of new, high-yielding, resistant varieties that would eliminate the need for chemical control and thus prevent the serious contamination and human health problems that it now causes.

Socioeconomic impact

Without resistant varieties to orange leaf rust, all the coffee growers will be negatively affected through diminished yields and increased production costs but it is the small producers (87 per cent) who stand to lose most because of their incapacity to pay for chemical control without which their whole crop may well be wiped out. In the worst cases, they will be forced to abandon coffee and go back to depending on their uncertain subsistence agriculture or to work on the big plantations as day labourers. At stake is the little and precarious independence they still cling to as peasant producers within the international network of coffee production. It is unlikely that many of the affected growers will be satisfactorily reabsorbed into the depressed agriculture of the southeast even as day workers. Their options, along with the redundant day labourers, will be limited to extreme conditions of rural underemployment or migration to swell the lower social strata of the overcrowded cities. Whether in the country or the cities, the increase in labour supply will help to keep wages and living conditions down and accelerate the process of concentrating land and wealth in the hands of a few big plantation owners.

On the other hand, the large growers are cushioned from the worst ravages of the disease by their ability to pay for chemical control; but they face diminished yields and profits. Although absolute production will no doubt drop slightly, the medium and large producers should have no real difficulty in keeping the industry supplied (they are responsible for 82 per cent of the production) so that the employment created through forward-linkage (in any case a small proportion) will not be seriously affected.

Villaseñor (1987) considers that orange leaf rust is not so serious a threat as it was initially thought to be. Changes in agricultural practices such as cultivation in the sun, the introduction of HYVs and the use of fungicides are keeping the disease under control though not preventing its spread.

We believe there are clear benefits to be gained for the whole range of producers from the application of APB to coffee. Yet, in terms of numbers and impact on living conditions, the small growers stand to gain most if the work is done, as presently planned, within the framework of a government-sponsored programme which will ensure small-producer access (through credit and price control) to the technology. Not only would it protect the livelihood of more than 93,000 small producers and a large proportion of the 270,000 day labourers but, by substantially increasing yields, it could also raise wages as well as the number of rural jobs. Although there would be a slight

reduction in labour demand due to the diminished need for the application of chemicals, the improvement of environmental and health conditions for the workers are likely to be enormous. Few official figures are available, but it is generally recognised by the World Health Organisation (WHO) that intoxication and serious illness from contact with agricultural chemicals are common in Third World countries (and Mexico is no exception) because of the lack of safety precautions and ignorance of the danger involved.

By increasing field productivity and production, the forward linkages in the industry would increase. As long as supply did not increase so much as to flood the highly fluctuating market, the impact would have an overall positive balance in the short term, especially for the early adopters. With continued APB research it would also be possible to achieve a long-term, environmentally-sustainable programme for coffee production. In terms of social structure the APB alone is not expected to alter the skewed access to land, and inputs, the almost feudal relations of production on some of the large plantations and the increasing pressure from demographic growth. But the technology could be used by the government to protect the small producers from losing their entire crops and livelihood.

Coconut

Coconut is an important tropical crop because of the large number of products which are derived from it and because it will grow in sandy, saline soils where little else can be cultivated.

Coconut has been called the tree of life because it produces all the basic human needs: food (from water and fresh copra), shelter (from leaves) and energy (through burning of the shell). One of the most important applications today is the production of coconut oil extracted from dried copra which contains a high percentage (48 per cent) of lauric acid, a short (12 C) saturated fatty acid that is solid at room temperature because of its high melting point. Lauric acid has a variety of uses in the production of margarine, soap, cosmetics, plasticisers for PVC, etc. (Woodroof, 1979). In Mexico, 90 per cent of the production is for copra and only 10 per cent is reserved for fruit. The dry copra yields about 60 to 70 per cent oil, 90 per cent of which is used for the production of soap and 10 per cent for food purposes.

It is calculated that an area around 800,000 hectares is suitable for coconut palms in Mexico. However, today only some 170,000 hectares are planted with this species of palm which, in 1986, produced over one million tonnes of fresh coconut and 175,000 tonnes of copra. Dwarfed by the large Asian producers (the Philippines, Indonesia and India alone have 4.93 million hectares and produce 25.4 million tonnes per year, which is 72.5 per cent of world production), the Mexican production seems unimportant from a world perspective. At a domestic level, however, it provides work for about 50,000 people, including small-holders, ejidatarios, agricultural day workers, drivers and industrial workers.

Coconut is cultivated in the five states of the southeast that make up 24 per cent of the national cultivated area of the crop. Tabasco is the third largest producer (27,700 hectares) and harvests over 26,000 tonnes of copra per year. In Yucatan there are some 3,311 hectares of coconut plantations mostly along the northern coast, but unlike the rest of the country where 90 per cent of the production is for copra, the vast majority (2,811 hectares) is used for fresh fruit production, which is sold locally along the coasts.

In other parts of the country 26 per cent of the coconut plantations are intermixed with other crops such as banana, mango, lemon, papaya, tamarind and improved grasses, but even in Yucatan where this is less so coconut production is rarely a campesino's primary economic activity. The crop demands little labour (on average 45 work days or one or two months per hectare per year) which makes it ideal for combining with other occupations, most commonly fishing and salt production in Yucatan. Fishing is far more economically rewarding and will usually be the coastal people's principal source of income. Nevertheless, coconut and copra provide significant additional resources to fall back on in return for very little effort. Management is unsophisticated and uses a very low level of technology. Only rarely are the ideal treatments applied (i.e. irrigation, weeding and the application of fertilisers) so that yields are correspondingly low: 20 tons/hectare of fresh fruit and 1.2 tons/hectare copra. However, the low guarantee price for copra and very inadequate credits from the local government for copra production in Yucatan provide little economic incentive for the producers to invest more. They are content with whatever can be harvested with little help from modern technology.

Lethal Yellowing (LY)

Coconut palms in Mexico are now threatened by the spread of Lethal Yellowing. This disease, which kills trees within five months from the moment the first symptoms appear, is caused by a mycoplasma-like organism (MLO) that develops in the sap of the infected trees. The pathogen is transmitted from diseased to healthy individuals by a small beetle (Myndus crudus) which feeds on the sap of the trees.

The disease was first detected in Mexico in 1981 on the Island of Cozumel, Quintana Roo, from where it soon spread across the sea to Cancun and then south to Tulum and west to El Cuyo. By August 1988 it had jumped to Tel Chac, a small fishing village further west on the Gulf Coast. Judging by the discontinuous way in which the outbreaks have occurred, always first appearing around ports, it is supposed that fishermen, who engage in part-time coconut production, are largely responsible for carrying the insect entangled in their hair, nets and clothes.

There is no cure for Lethal Yellowing; the symptoms can be delayed by applications of oxytetracyclin but the trees are doomed as soon as the antibiotic is withdrawn. To some extent, its spread can be halted by spraying insecticides. However, the beetle dwells on the grasses and it is impracticable to spray a sufficient area to be effective.

Until recently, it appeared that the disease was advancing at an average pace of 25 kilometres per year. However, the rate could be speeded up at any moment. It is as yet unknown what impact the uncommonly strong hurricane "Gilbert", which crossed Yucatan in September 1988, will have on spreading the LY. It seems inevitable that it will reach Campeche and Tabasco from where it could cross the Isthmus of Tehuantepec and reach Oaxaca, Guerrero and the rest of the Pacific Coast. The prospect of losing all the Atlantic Coast plantations which, according to present evaluations appear to be 100 per cent susceptible to the disease (and half of the ones on the Pacific Coast) is a daunting one which could have a profound socioeconomic effect on producers, day labourers, fishermen, and all those industries that depend on copra and coconut oil for their raw materials. The lack of palm trees could also affect the tourist industry, since palms constitute one of the important aesthetic attractions.

It seems impossible to control the spread of the disease for any length of time. The only real alternative is to plant resistant varieties, a colossal task that implies replacement of all or a great part of the existing plantations.

State of the art: APB

Coconuts and oil palms do not produce suckers and have morphological characteristics that make them very difficult to propagate vegetatively. They have only one stem and it does not produce any shoots; furthermore, it has only one vegetative bud (the apex) and all axillary buds differentiate into inflorescences. This makes it impossible to propagate them vegetatively through traditional methods such as cuttings or grafting. They can be propagated sexually, however, but the rates are very slow and when controlled pollination is used to produce a homogeneous progeny from known parents, it is reduced further (Pannetier and Buffard Morel, 1986). Coconut palms show a great deal of heterogeneity in vigour and productivity and the long life cycle of the tall varieties, which take over seven years before producing nuts, makes the production of hybrids a very complicated and slow process. It has been calculated that it takes about 16 years to release a new hybrid. Vegetative propagation would therefore be extremely useful for coconut cultivation and breeding since it would be possible to multiply elite high-yielding individuals or, more important in our case, disease-resistant types would allow a more rapid release of successful hybrids from breeding programmes. In vitro tissue culture offers the only possibility for the asexual propagation of coconut palms.

In spite of a large amount of research in several countries, the in vitro culture of coconut tissues has not been as successful as with oil palms (Eleis guinensis) (Corley, 1982). Several methods have been tried with different degrees of success by groups principally in France, the Philippines and the United Kingdom.

Somatic embryogenesis: Somatic embryos are reported to form on partially dedifferentiated callus originated, under the influence of very high 2,4-D concentrations. The nodular callus from leaf explants produced masses of embryoids that did not develop into plants (Pannetier and Buffard-Morel, 1986). Work at Wye College (Blake, 1989) has produced plants from inflorescence derived "calloid". Although this method has regularly yielded small numbers of plantlets from at least 20 mother plants, none of them has been established in soil probably due to an unfunctional root system. So far, only one in vitro formed coconut palm produced by Unilever in the United Kingdom has been successfully established in the Solomon Islands (cited by Blake, 1986). Direct embryogenesis from leaf tissues was reported by Raju and collaborators (1984); unfortunately, they do not give any details of the protocol used or the efficiency of the method. No confirmation of the successful applicability of this technique has been published.

Other approaches such as the reversion of flower meristems into vegetative shoots bypassing the callus stage (Pannetier and Buffard-Morel, 1986) or the direct embryogenesis from pollen grains (Monfort, 1985) have yielded embryoids but these have not progressed into whole plants.

Zygotic embryos: The in vitro culture of zygotic embryos was first developed by the Guzman's group in the Philippines to rescue the embryos of the Makapuno variety which do not germinate in the nut. More recently, the in vitro germination of embryos from other varieties has been reported although with variable degrees of success (see Blake 1989 for review). The work with the Makapuno variety shows the applications that can be derived from the technique. Makapuno-type nuts have a jelly endosperm instead of the normal

one of copra and water that is a highly-appreciated delicacy. Generally, only a few nuts in a tree are Makapuno type. However, trees derived from the rescued embryos have a much higher proportion of them though rarely 100 per cent. A laboratory for the mass propagation of this variety has been established by the Philippine Coconut Research and Development Foundation.

In spite of reports by Sasson (1988) and Tudge (1988) that the methods to micropropagate coconut palms are ready for commercial exploitation, it seems that considerable advances in this technology will have to be made before tissue culture can be applied to improve coconut production. In its present state, the very low rates of embryogenesis combined with the long periods in culture make it a very inefficient micropropagation method. However, there is no reason to believe that the difficulties will not be overcome eventually just as in the case of so many monocots that were considered impossible to regenerate in culture only a few years ago.

The long callus stages under the influence of very high concentrations of regulators cast doubts on the genetic stability of the plants derived from such systems. A very high incidence of abnormal flowers and fruits was recently disclosed in apparently normal oil palm clonal trees planted by Unilever in Malaysia (Soh, reported by Agricell Reports, 1988). The abnormalities, considered to be due to somaclonal variation, are a very clear warning of the risks posed by such long-term in vitro systems. The field testing of in vitro cloned plants carried out by French researchers at IRHO and ORSTOM have shown no abnormalities so far. However, the final evaluation is not expected until 1990 (Sasson, 1988).

In Mexico a programme for the production of hybrids between LY sensitive tall varieties and dwarf-resistant types has been underway for several years at the experimental station of INIFAP, Guerrero. Some hybrids have been planted in the Caribbean to test them for resistance to LY in an infected area. However, even if the trees show the desired traits, it will be a very long time before they can produce enough seed for extensive plantations. Furthermore, if already proven resistant varieties such as the Malayan Yellow Dwarf or the Maypan hybrids produced by the Coconut Board of Jamaica, were to be planted there would also be a great shortage of germplasm. This is why an efficient micropropagation method would be so useful.

Research on embryo rescue is being carried out at INIFAP, Zacatepec (Méndez-Salas personal communication) to back the hybrid production programme in Guerrero. In collaboration with Wye College, London, other research projects are under way at UACH and at CICY. These initiatives should become a long-term concerted effort to develop methods to micropropagate hybrids and elite materials that might not only resist LY but also increase yield. However, Mexico should take other immediate action in the fight to curb the advance of LY. The first should be a contingency plan to replant with Malayan Dwarfs (Romney, 1977) or whatever resistant germplasm is available, irrespectively of yield and characteristics of the oil and copra to prevent total losses in the southeast. Secondly, to resort to more traditional methods and, as suggested by Harries (personal communication) a screening programme should be established to look for disease resistance among the germplasm available in the country.

Threats of substitution

Although coconut trees offer a variety of commodities, oil is its most important and valuable product and for some countries such as the Philippines, an important export product.

Many industries would like to see a temperate zone annual crop such as rapeseed or soybeans produce seed oils rich in laurate (as soconut) instead of oleate or linoleate which are long chain (18C) unsaturated acids (Knauf, 1987). Caprate (10C) and laurate (12C) are intermediaries in the synthesis of all long chain fatty acids in all plants and coconut manages to stop the elongation process and accumulate laurate. It has not yet been discovered how this is done but it is known that an enzyme (acyl-ACP thioesterase II) found in the mammary glands of rats prevents the elongation performed by another enzyme (fatty acid synthetase) around 10, 12 and 14C length and this illustrates what could be achieved through genetic engineering: a rat gene inserted inside a rapeseed could produce a vegetable oil similar to that of coconut far away from tropical countries. It is still only a possibility but the long-term threat of substitution exists.

Socioeconomic impact

In the long term APB might play a significant role in fighting LY and thereby maintaining the coconut plantations. As such, it would also help maintain rather than change the social structures and employment opportunities related to coconut and copra production. Although the number of people who depend economically on the crop is considerable (about 50,000), it is not the primary source of income for the majority of the population. Nevertheless, in specific ecological zones it is the only crop that will grow and losing it would have a serious negative impact on the poor sections of the local population. Because LY has become a national threat, to both large and small producers, the possibility of a government sponsored APB programme being implemented is rather high. But, as it has already been stressed, this is a long-term undertaking the final outcome of which is impossible to predict at this stage.

FUTURE POTENTIAL OF APB IN MEXICO

Unlike most of the scientific and technological developments of this century (including the GR) plant biotechnology has been described as a biological revolution which holds great promise for LDCs. It is said that crops for marginal lands and low-input agriculture will improve the harvests of large numbers of small producers throughout the world. Is this really true? Although the new technology is promising, it is doubtful that LDCs will be able to extract great benefits from it. There is no question about the breadth and scope of biotechnological possibilities, but they have been described and promoted in a very general manner, e.g. "APB will produce all sorts of plants resistant to disease, pests and stressful conditions". This makes it appear as if it were true for all crops and problems and just round the corner waiting to be grasped. However, it is not the case, at least for the time being. Each species presents advantages and difficulties in its manipulation and each problem requires a specific genetic trait or set of traits to counteract it. Therefore, it is impossible to generalise. For example, although tomato plants can be engineered with toxin genes from bacteria to protect them against the larvae of lepidopterans that eat its leaves (Fischhoff et al., 1987), the genetic fabrication of an orange tree resistant to the Mexican fruit fly whose larvae develops within the fruit is a completely different matter. Will it be possible in the future? Maybe. The theoretical potential of APB seems to be unlimited but an enormous amount of costly basic research and organisation is still required before such achievements can reach the hands of producers in the LDCs.

This is not to say that Mexico and other LDCs will not benefit at all from some agricultural biotechnologies. The private sector, large farmers and industrialists certainly stand to gain, as we discuss below, but the benefits

will be small in comparison with those reaped by the DCs and will be limited to a few species among which ornamentals are the most prominent.

In this paper we have analysed the situation of only a few crops because of their economic importance for the southeast of Mexico and because the research being carried out on them has the potential to be applied. Nevertheless, even in these favourable cases, application is not an inevitable next step for two main reasons. Firstly, due to the country's structural limitations in the production and transfer of technologies and secondly, because of the reluctance of the users to take the economic risks involved in adopting innovations.

Obstacles to the development of APB in Mexico

With very few exceptions (amongst which Brazil and India are outstanding) most LDCs suffer from some or all of the following obstacles to developing APB:

1. Lack of well-defined national programme on biotechnology;
2. a shortage of highly qualified researchers;
3. weak links between basic and applied research;
4. limited economic resources;
5. small private participation in the field; and
6. limited economic feasibility of the technologies.

National programme on biotechnology: The country's potential is limited by the lack of a well-defined national policy to develop biotechnologies. It should be noted that biotechnology is recognised by the authorities as a potentially important area for the country's commercial and economic development and has been assigned top priority by the National Council of Science and Technology in its programmes in accordance with the national programme on science and technology (Gobierno Constitucional, 1984a). However, in spite of the fact that some analytical studies have been carried out by the Fundación Barros Sierra (Quintero, 1985, CONACyT (Quintero, in press and CEPAL, 1988), no specific areas or lines of research have been defined as national priorities. Even where certain problems have been identified, action is slow to follow or is not taken at all. As an example, we can cite the case of Lethal Yellowing. The disease was unmistakably diagnosed in Mexico in 1982 and the need was clearly established in a meeting in Merida in 1984 (Quintero, in press) to develop PTC techniques for the micropropagation of coconut palms and to carry out basic research to develop diagnostic methods. However, it was not until 1988, mainly through individual initiative, that some work on the topic began.

Without a general framework and the identification of priorities, the allocation of resources and the selection of applied lines of research has been based on the individual interests of scientists.

Qualified human resources: In the case of Mexico the lack of highly-qualified human resources is a limiting factor but not a crippling one. In comparison with the United States, Europe and Japan the Mexican research capability is very small. Nevertheless already there are some research centres that are capable of adopting or developing plant biotechnologies and several M.Sc. and Ph.D programmes (CICY, CINVESTAV-I, CP Chapingo, UNAM-CIFN and UNAM-FQ) that should enable the country to increase

its qualified human resources fairly quickly. On the other hand, there is a growing awareness and interest in APB - the subject is taught at B.Sc. level in most biological sciences and agricultural curricula.

Links between basic and applied research: Many scientists in Mexico consider that the pursuit for knowledge should be the one and only objective of scientific research. They look down on those who get their hands dirty searching for solutions to practical problems. Biochemists and molecular biologists consider that agronomists are closer to farmers than to scientists, while the latter accuse the former of locking themselves in "ivory towers". Until recently both groups could survive without much interaction but with the development of APB, this situation has changed. There is an urgent need for closer collaboration if APB is to be successfully applied. As yet it has proved very difficult to bridge the gap between the two groups.

Limited economic resources: It is unrealistic to expect that much of the R&D done in DCs will be of direct benefit to the agricultural challenges of Mexico and particularly those of the southeast. Firstly, because DCs are concerned primarily with solving their own problems and maximising profits and secondly, because the agricultural characteristics of the southeast make it an unattractive market. As L.V. Mayer (1988), Deputy Assistant Secretary for economics of the US Department of Agriculture, succinctly told the Agbiotech 88 meeting in Washington: "The low incomes of the hungry prevent them from becoming viable commercial customers". R&D from DCs will therefore largely reach LDCs through two channels: 1) incidentally, as a by-product of research done for other purposes, and 2) if it is directed through multinationals which have a stake in the region. In both cases, patents will ensure that LDCs pay dearly for the new technology. At present, Mexico does not recognise plant patents but this is due to change in the near future. Therefore, the implications are that if it wants to make use of APB, Mexico will have to do most of the research itself which will be a very expensive undertaking.

Until now most APB research projects in Mexico have been financed by the grant systems of CONACyT and COSNET and by SARH. However, during the present financial crisis there is little hope of sufficient public funds being channeled to research institutions to ensure an adequate transformation of ideas into reality. The new policy of making the government research centres (SPP-CONACyT) economically as self-sufficient as possible clearly manifests the government's intention of reducing its support for basic research.

The role of the private sector: For a biotechnology to have an economic impact it is essential that there is a user that not only needs it but that has the financial possibility to adopt it. Many research projects on APB in Mexico are undertaken on the researcher's initiative in the hope that the results will convince someone later on. Consequently, many of them have to be abandoned due to lack of financial support or because of the impossibility of transferring a product to the field for evaluation. If anyone in Mexico can make use of APB it will be the private sector. Not only does it have the economic capacity to fund the necessary research, but as an early adopted, it will be able to capture and dominate the markets. Furthermore, entrepreneurs are receiving the lion's share of government backing: firstly through tax deduction incentives to finance research. Secondly, the government is now encouraging its research centres to turn to private industry for contracts and is therefore putting at the latter's disposal a very large and expensive research capacity. Finally, the shared-risk schemes available through CONACyT and Nacional Financiera (NAFINSA) to finance research and development nearly at the production stage, remove some of the economic risk from the projects for the client.

Nevertheless, private capital will only be put forward for biotechnology ventures where there is a clear market for the end product. Looking at agricultural producers in Mexico, only a very small percentage (less than 2 per cent) can be classified as large producers (CEPAL, 1982) who would have access to sufficient resources to invest in APB and they would only take the decision to do so if the price they will get for their products justifies the additional input costs. The guarantee prices of maize, beans, sugar and many other crops is too low to stimulate further investment. If left to market forces, then it is difficult to see how APB will be applied to the crops that could positively affect the vast majority of producers and consumers. There is also great scepticism among the private sector that the new techniques will live up to their promise. Producers are very reluctant to invest in something that has not yet proved to be of superior quality in the field, especially since the returns are unlikely to accrue for several years. In the cases we have analysed here neither the henequen nor the coffee plants that are being tested in plantations have proved their merit in a conclusive manner. In the same way, the suggestion that virus-free orange trees derived from tissue culture are going to increase yield is nothing but a theoretical possibility to the producers of the southeast.

With the exception of the cut-flower industry in which a great deal of foreign interests exists, only the tequila industry and a couple of other companies have taken the initiative. They are financing APB projects under confidential agreements with public research centres.

It is fundamental that whoever finances APB, whether the government, private industry or producer associations, they should be conscious of the limitations and difficulties involved and be prepared to sustain multi-disciplinary programmes for many years beyond the boundaries of the six-year government periods. It is relevant to point out that the tissue culture work on oil palm at IRHO started in 1970 (Sasson, 1988) and the definitive evaluations on the performance of the in vitro produced plants are not expected until 1990, 20 years later. It should also be borne in mind that there are no permanent solutions to disease and pest resistance because of the continuous evolution of pathogens and predators. It is therefore essential to carry out continuous and long-term APB programmes in an attempt to keep pace with natural changes.

Economic feasibility: The potential of a specific plant tissue culture technology is usually based on positive results reported in research papers. However, in many cases the plants produced have never left the laboratory, probably not even the test tube. As commercial micropropagators know only too well, this information is of no practical use since it pays little or no attention to many very important aspects such as multiplication and survival rates, genetic stability and trueness to type of the products. Also it completely disregards the costs of producing thousands of the new plants with the method.

Estimating costs is very difficult because of the many factors involved. For instance, labour, which accounts for 60-70 per cent of the total cost, is particularly variable being dependent on skill and efficiency. High inflation rates in Mexico add to the difficulties (during 1987 the inflation rate reached 150 per cent). Micropropagated plants are always considerably more expensive than traditionally-propagated ones. This is understandable since micropropagation techniques are labour intensive and one has to add the expenses of weaning in mist or green houses and time in the nurseries to those of the laboratory. It is therefore not surprising that the private sector has been so reluctant to invest in something whose merits have not been proven in the field and the profits from which will not start to flow for several years.

Jones (1982) has calculated that each cloned oil palm plantlet costs five times as much as a seed propagated one but that the extra cost would be rapidly recovered if there is an increase of 30 per cent in oil yield and that profits can be made after the fifth year of harvest. He also estimates that to be cost effective a micropropagation unit must produce in excess of a million plantlets per year.

Although manual labour is relatively cheap in Mexico (at least 10 times cheaper than in the US) it is imperative to reduce costs before tissue culture can become more widely applied to low-value crops. The formation of somatic embryos from single cells grown in fermenting tanks is at present the most efficient system known to produce large numbers of plants in short times with relatively little labour. In addition, somatic embryos can be encapsulated in alginates to form artificial seeds which will further reduce costs, making handling easier (Fujii et al., 1987). Nonetheless, the technique cannot be applied yet to many species and poses the risk of genetic instability. It might be possible to apply it more widely as our knowledge of the mechanisms that control differentiation and gene expression increases.

Automation of certain tissue culture processes is also progressing (Levin et al., 1988) but as yet it is unknown whether they will be able to compete with Mexico's cheap labour.

Comments on the selected crops

The four cases we have analysed here illustrate some of the general points we have discussed above.

The advance in some fields and in certain crops cannot be taken as a basis for predictions in other species and even results reported in the scientific press may still be far away from application. One of the cases we have analysed here illustrates this point. It was thought that micropropagation work on coconut palms would follow in the footsteps of the oil palm work done by Unilever in the United Kingdom and IRHO in France, which is already commercialised in several parts of the world (Corley, 1982; Sasson, 1988). An optimistic prediction by Branton and Blake (1983) when they first produced a clonal coconut plant, has permeated to Sasson (1988) and Tudge (1988) who report that, from the work at Wye and IRHO, coconut micropropagation is ready for large-scale commercialisation. Tudge (1988) also reports that at Hindustan - Lever (Bombay, India) coconut micropropagation is "on the point of commercial success". However, at least to our knowledge, there is still no available technique for the efficient micropropagation of coconuts. Furthermore, the abnormalities found in Unilever's oil palm plantations in Malaysia indicate that the cloning methods used for oil and coconut palms with long periods in vitro are not safe.

The case of citrus illustrates a totally different example of how a proven biotechnology developed in other countries, in this case the United States and Spain, could be exploited by LDCs in the short term. The in vitro quarantine methods and release of disease-free budwood for commercial propagation as developed by the citrus variety improvement programme of Spain, can be transferred to any country for its own benefit. Navarro has made very detailed recommendations as to how the quarantine programmes should be carried out and the Instituto Valenciano de Investigaciones Agrarias offers to train scientists from other countries in order to help implement them. However, growers in Mexico are not easily convinced of the benefits of these programmes since it is difficult to quantify the benefits due to reduced losses and the economic returns are long term.

The agaves is an example of a very successful methodology developed in Mexico for a very specific purpose. However, it illustrates once more that the factors determining whether a biotechnology will be applied or not do not rest on its potential or on the need for it, but on who can pay for it. It is doubtful that the production of henequen will receive the potential benefit of an increased yield (that would have such a positive impact on the thousands of henequen workers in Yucatan) because of the low world price and the present henequen production system. Nevertheless, the privately-owned tequila industry is financing agave production in the laboratory and carrying out field tests. The industry can afford the expense since it is a high-value export product which makes it easy to recover the initial investment in a relatively short time.

The case of coffee could be one example of APB reaching the producers since the government institution, INMECAFE, has already taken the first steps by financing the research and is now testing the new resistant plants in the field. It is yet to be seen how good their performance is and at what cost they will be distributed. It should be mentioned that there is opposition to the use of APB techniques for the control of orange leaf rust amongst agronomists who think that the disease can be more efficiently controlled with traditional methods.

Conclusions

If we are correct in assuming that APB will only be adopted to a limited extent in Mexico in the short to medium terms and largely within the private sphere, it follows that the majority of its direct benefits will also be restricted to certain high-value crops and to those who produce and consume them. Therefore, poor consumers cannot expect to benefit from a general reduction in food prices, as occurred in the GR, at least for a while. Indeed, the relatively greater profits from high-value crops will continue to encourage farmers to abandon staple crops, making food scarcities more probable.

While the adoption of APB in specific crops such as bananas, coffee and coconut, is likely to reduce employment in the southeast, it is doubtful whether it would directly create many new jobs for agricultural workers and producers. Some privileged areas, such as the Puuc region, might be able to intensify production, but in comparison with the magnitude of the problem of rural under and unemployment it is unrealistic to conceive of APB as a panacea. Moreover, the majority of new jobs would be the ones for day workers at a minimum wage. In the short term, the creation of independent jobs depending more on the provision of irrigation and communications infrastructure by the government than on new agricultural technology.

Job loss from APB-facilitated mechanisation, on the other hand, is not an immediate threat in the southeast because of the adverse ecological conditions. Mechanisation is only likely to intensify at the food-processing stage and only on a small scale, due to the relative cheapness of labour and the lack of capital for long-term substitution.

The adoption of varieties which no longer require pesticide protection or fertilisers would slightly diminish labour demand but the benefits to human health and the environment would more than compensate for this. On the positive side, a few technical jobs would be created to run the APB laboratories.

In summary, it would appear that APB in itself is not one of the keys to socially and environmentally-sustainable development in the southeast of Mexico although it could be a powerful secondary tool. Ultimately, it is the underlying structure of Mexican agriculture and the rural development policies adopted that will determine the future agricultural growth and the distribution of the benefits. So long as present imbalances regarding access to credit, irrigation and the commercialisation of products are not corrected, APB adoption will continue the trend of favouring commercial agriculture and high value crops, while its potential to relieve poor consumers and producers and diminish technological and food dependence will largely remain dormant.

NOTE ON CITRUS GROWERS' INCOME

On a well managed, irrigated plot a producer can expect a yield of at least 18 tonnes per hectare. With 1.7 hectares, in 1988 he could have sold his production of 30.6 tonnes to the Akil plant for \$7,650,000 pesos (or more if he had sold some in the local market of Oxcutzcab before the processing season). According to a CONAFRUT estimation, total production costs in 1988 for 1 hectare amounted to \$1,540,000 (see table ...). Thus, once his expenses had been covered (\$2,618,000) the producer could expect a net income of \$5,032,000 or almost double the minimum salary.

This does not take into account the fact that if the producer managed his plot well and spent the full amount on inputs, he probably obtained a much higher yield or, inversely, if he obtained a lower yield, it is likely he spent less. Either way, his net income was in all likelihood more than calculated here. Nor does it take into consideration other incomes the producer or his relatives may have.

REFERENCES

- Aceves Navarro, E. (1988). "Uso y manejo del agua en la agricultura mexicana", Comercio Exterior 38(7): 570-577.
- Ahmed, I. (1988). "The Bio-revolution in agriculture: Key to poverty alleviation in the Third World", International Labour Review, Vol. 127, No. 1.
- Bajaj, Y.P.S. (1983). In vitro production of haploids", in Evans, D.A., Sharp, W.R., Ammirato, P.V. and Yamada, Y. (eds.) Handbook of Plant Cell Culture, Vol I. Techniques for Propagation and Breeding, Macmillan, New York, pp. 228-287.
- Baños Ramirez, O. (1988). Ejididos sin ejidatarios, Ph.D. Thesis, El Colegio de México, México, D.F.
- Barlass, M. and Skene, K.G.M. (1986). "Citrus (Citrus species)", in Bajaj, Y.P.S. (ed.) Biotechnology in Agriculture and Forestry, Vol. 1: Trees 1, Springer-Verlag, Berlin.
- Benitez, F. (1956). Ki, el drama de un pueblo y una planta, Fondo de Cultura Económica, México, D.F.
- Blake, J. (1989). "Coconut (Cocos nucifers) micropropagation", in Bajaj, Y.P.S. (ed.), Biotechnology in Agriculture and Forestry, Vol. 10: Legumes and Oilseed Crops I, Springer-Verlag, Berlin, in press.
- Brannon, J. and Baklanoff, E.N. (1987). Agrarian Reform and Public Enterprise in Mexico: The Political Economy of Yucatan's Henequen Industry, The University of Alabama Press, Tuscaloosa, Alabama.
- Branton, R. and Blake, J. (1983). "A lovely clone of coconuts", New Scientist, 98, 554-557.
- Buttle, F.H. Kenney, M. and Kloppenburg, J. Jr. (1985). From Green Revolution to Biorevolution: Some observations on the changing bases of economic transformation in the Third World", Economic Development and Cultural Change, 34, 31-55.
- Button, J. and Koshba, J. (1977). "Tissue culture in the citrus industry", in Reinert, J. and Bajaj, Y.P.S. (eds.) Applied and Fundamental Aspects of Plant Cell Tissue and Organ Culture, Springer-Verlag, Berlin.
- CEPAL, (1988). Desarrollo biotecnológico en la producción alimentaria de México: Orientaciones de política, Report prepared by Arroyo, G. and Waissbluth, M. (mimeographed).
- (1982). Economía campesina y agricultura empresarial, Siglo XXI, Mexico, D.F.
- Cocking, E.C. (1988). "Producing fertile somatic hybrids", in Applications of Plant Cell and Tissue Culture, Ciba Foundation Symposium 137, pp. 75-89, Chichester, John Wiley and Sons, Chichester.
- Coll-Hurtado, A. (1985). Es México un país agrícola? Siglo XXI, 2a edición, Mexico, D.F.
- Corley, R.H.V. (1983). "Cloning planting material for the oil palm industry", The Planter 58, 515-528.

- Cruz, C., Del Castillo, L., Robert, M.L. y Ondarza, R.N. (eds.) (1985). Biología y aprovechamiento integral del henequén y otros agaves, Centro de Investigación Científica de Yucatán, A.C. Mérida, Yucatan, Mexico.
- Cuozo, M., O'Connell, K.M., Kaniewski, W., Fang, R., Chua, N. and Tumer, N.E. (1988). "Viral protection in transgenic tobacco plants expressing the cucumber mosaic virus coat protein or its antisense RNA", Bio/Technology 6, 549-557.
- Eastmond, A., González, R.L., Lozoya Saldaña, H. and Robert, M.L. (in preparation). La Biotecnología Vegetal en México: Una Revisión Crítica de su Potencial.
- Einset, J.W. (1978). "Citrus tissue culture: Stimulation of fruit explant cultures with orange juice", Plant Physiology, 62, 885-888.
- Evans, D.A. and Sharp, W.R. (1986). "Applications of somaclonal variation", Biotechnology 4, 528-532.
- FAO (1987). Trade Yearbook, 1986 Vol. 40, FAO, Rome.
- (1987b). Production Yearbook, 1986 Vol. 40, FAO, Rome.
- Fischhoff, D.A., Bowdish, K.S., Perlak, F.S., Marrone, P.G., McCormick, S.M., Niedermeyer, J.G., Dean, D.A., Kusano-Kretzmer, K., Mayer, E.J., Rochester, D.E., Rogers, S.G. and Fraley, R.T. (1987). "Insect tolerant transgenic tomato plants, Bio/Technology 5, 807-813.
- Flynn, J. (1986). "Want some O.J? It's fresh from the test tube", Business Week, November, pp. 79-80.
- Fujii, J.A.A., Slade, D.T., Redenbaugh, K. and Walker, K.A. (1987). "Artificial seeds for plant propagation", TIBTECH 5, 335-339.
- García, A. y De Sicilia A. (1984). El Mercado Mundial de las Fibras Duras. Centro de Investigación Científica de Yucatán, A.C., Mérida, Yucatan, Mexico.
- George, E.F. and Sherrington, P.D. (1984). Plant propagation by tissue culture, Exegetics Ltd., Basingstoke, England.
- Gobierno Constitucional de los Estados Unidos Mexicanos (1984a). Programa Nacional de Desarrollo Tecnológico y Científico, 84-88.
- Gobierno Constitucional de los Estados Unidos Mexicanos y Gobierno Constitucional de Yucatán, (1984b), Programa de Reordenación Henequenera y Desarrollo Integral de Yucatán.
- Guzman de, E.V. and Manuel, G.C. (1977). "Improved root growth in the embryo and seedling cultures of coconut Makapuno by the incorporation of charcoal in the medium", The Philippine Journal of Coconut Studies, 2, 35-39.
- Hewitt de Alcántara, C. (1978). La Modernización de la Agricultura Mexicana 1940-1970, Siglo XXI, Mexico, D.F.
- Hu, C. and Wang, P. (1986). "Embryo culture: Techniques and applications", in Evans, D.A., Sharp, W.R. and Ammirato, P.V. (eds.), Handbook of Plant Cell Culture, Vol. 4, Macmillan, New York, pp. 43-96.
- Instituto Nacional de Estadística, Geografía e Informática (1986a). X Censo General de Población y Vivienda, 1980, Resumen general Vols. I and II, Mexico, D.F.

- (1986b). Anuario de Estadísticas Estatales 1986, Mexico, D.F., Mexico.
 - (1986c). Comparaciones internacionales Mexico en el mundo, Mexico, D.F.
 - (1986d). Realides numéricas, imagenes censales, Mexico, D.F.
 - (1985). Estidísticas Históricas de Mexico, tomos I Y II, Mexico, D.F.
 - (1973). IX Censo general de poblacion y vivienda, 1970, Mexico D.F.
- Joffe, S. and Greeley, M. (1987). "The new plant biotechnologies and rural poverty in the Third World", Paper prepared for Appropriate Technology International, Washington, D.C.
- Kenney, M. and Hibino, B. (1987). Biotechnology in Mexican Agricultural Research: Development of a Research Agenda, Paper presented at 1987 Rural Sociological Society Annual Meeting in Madison, Wisconsin, August 12-15.
- Kingsman, S.M. and Kingsman, A.J. (1988). Genetic Engineering, Blackwell, Oxford, pp. 189-232.
- Kloppenburger, J. Jr. (1984). "The social impacts of biogenetic technology in agriculture: Past and future", in Berardi, G.M. and Geisler, C.C. (eds.) The Social Consequences and Challenges of New Agricultural Technologies, Westview Press, Boulder.
- Kloppenburger, J. Jr. and Kleinman, D.L. (1987). "The plant germplasm controversy", BioScience 37, 190-198.
- Kobayashi, S., Ohgawara, T., Ohgawara, E., Oiyama, I. and Ishii, S. (1988). "A somatic hybrid plant obtained by protoplast fusion between navel orange (Citrus sinensis) and satsuma mandarin (C. unshiu)", Plant Cell Tissue and Organ Culture, 14, 64-69.
- Koshba, J., Ben Hayyim, G., Spiegel-Roy P., Neuman, H. and Saad, S, 1982. "Selection of salt tolerant callus cell lines and embryos in C. sinensis and C. aurantium", Zeitschrift fur Pflanzenphysiologie 106, 111-118.
- Levin, R., Gaba, V., Tal, B., Hirsch, S. and Denola, D. (1988). "Automated plant tissue culture for mass propagation", Bio/Technology 6, 1035-1040.
- López Huebe, R. and García de Fuentes, A. (1984). Manual de información básica de la región henequenera de Yucatán, Centro de Investigación Científica de Yucatán, A.C., Mérida, Mexico.
- Lozoya Saldaña, H. (1985). "Micropropagación vegetal", Ciencia y Desarrollo 65 Año XI, CONACyT, Mexico, Nov. Dic. pp. 63-70.
- Madrigal Lugo, R. and Bailón, R. (1987). "Aplicaciones de la biotecnología en cultivos agroindustriales: El caso de café", in La Agroindustria en México, Ier Seminario Nacional sobre la Agricultura en Mexico, Universidad Autónoma de Chapingo, Mexico.
- Marin, M.L. and Duran-Vila, N. (1988). "Survival of somatic embryos and recovery of plants of sweet orange (Citrus sinensis) (L.)Osborne After immersion in liquid nitrogen", Plant Cell, Tissue and Organ Culture 14, 51-57.
- Martínez-Morales, G., Villareal Ruíz, C. and Madrigal Lugo, R. (1988). "Comportamiento en campo de cafetos propagados in vitro", Resúmenes, XII Congreso de Fitogenética, 18-22 July, Chapingo, Mexico.

- Mayer, L.V. (1988). "Biotechnology and U.S. agricultural trade", in AgBiotech 88, Proceedings of the conference held in Washington D.C., Jan 26-28.
- Monfort, S. (1985). "Androgenesis of coconut - Embryos from anther culture", Zeitschrift fur Pflanzenzuchtung 94, 251-254.
- Navarro, L., Ballester, J.E., Juarez, J., Piña, J.A., Arregui, J.M. and Bono, R. (1981). "Development of a program for disease free citrus budwood in Spain", Proc. of the Int. Soc. of Citriculture 1, 70-72.
- Navarro, L. and Juárez, J. (1977). "Elimination of citrus pathogens in propagative budwood, II. in vitro propagation", Proc. Int. Soc. Citriculture, 3, 973-987.
- Navarro, L. Ortiz, J.M. and Juárez, J. (1985). "Aberrant citrus plants obtained by somatic embryogenesis of nucelli cultured in vitro", Hort. Science 20, 214-215.
- Nelson, R.S., McCormick, S.M., Delannay, X., Dubé, P., Layton, J., Anderson, E.J., Kaniewska, M., Proksch, R.K., Horsch, R.B., Rogers, S.G., Fraley, R.T. and Beachy, R.N. (1988). "Virus tolerance, plant growth, and field performance of transgenic tomato plants expressing coat protein from tobacco mosaic virus", Bio/Technology 6, 403-409.
- Nolasco, M. (1985). Café y Sociedad en México, Centro de Ecodesarrollo, Mexico.
- Pannetier, C. and Buffard-Morel, J. (1986). "Coconut palm (Cocos nucifera L.)", in Bajaj, Y.P.S. (ed.) Biotechnology in Agriculture, Vol. I: Trees 1, Springer-Verlag, Berlin, pp. 430-450.
- Quintero, R. (compilador) (1985). Prospectiva de la Biotecnología en México, Fundación Javier Barros Sierra y CONACyT, Mexico.
- Quintero, R. (In press). El Desarrollo de la biotecnología en México. Evaluación de Oportunidades, CONACyT, Mexico.
- Raju, C.R., Kumor, P.P., Chandramohan, M. and Iyer R.O. (1984). "Coconut plantlets from leaf tissue cultures", J. Plant Crops, 12, 75-78.
- Robert, M.L., Herrera, J.L., Contreras, F. and Vázquez, M. (in preparation). Large scale propagation of Agave fourcroydes Lem (henequen): Morphological stability and improved growth in the nursery.
- Robert, M.L. "Micropropagation de Agave tequilana Weber", Unpublished report for Tequila Cuervo.
- Robert, M.L., Herrera, J.L., Contreras, F. and Scorer, K.N. (1987). "In vitro propagation of Agave fourcroydes Lem. (Henequen)", Plant Cell, Tissue and Organ Culture, 8, 37-48.
- Robert, M.L. and Loyola-Vargas, V.M. (eds.) (1985). El Cultivo de Tejidos Vegetales en México, CICY-CONACyT, Mexico.
- Roca, W.M., Amézquita, M.C. and Villalobos, V.M. (1986). Estado Actual y Perspectivas de la Biotecnología Agrícola en América Latina y el Caribe, CIAT, Cali.

Rhodes, C.A., Pierce, D.A., Mettler, I.J., Mascarenhas, D. and Demeter, J.J. (1988). "Genetically transformed maize plants from protoplasts", Science 240, 204-207.

Rodriguez Vallejo, J. (1988). "La producción y la demanda de granos básicos en México", Comercio Exterior 38(7), 606-623.

Romney, D.H. (1977). "Replanting with Malayan dwarfs: A case study in Jamaica", Oleagineux, 32, 55-58.

Samson, J.A. (1980). Tropical Fruits, Longman, London.

Sasson, A. (1988). Biotechnologies and Development, UNESCO and Technical Centre for Agricultural and Rural Cooperation, France.

Secretaría de Agricultura y Recursos Hidráulicos (1984). Agenda de Información Estadística Agropecuaria y Forestal 1984, Mexico.

Secretaría de Programación y Presupuesto e Instituto Nacional de Estadística, Geografía e Informática (1983). X Censo General de Población y Vivienda 1980, Estado de Yucatán, Vols. I and II, Mexico.

Secretaría de Programación y Presupuesto (1979). La población de Mexico, su ocupación y sus niveles de bienestar, Mexico, D.F.

--- (1978-79). Manual de estadísticas básicas sociodemográficas, Vol. 1, sector población, Mexico, D.F.

Soh, A.C. (1988). "Oil palm micropropagation: Unexpected variation in field tests", Agricell reports 11, 34.

Sondahl, M.R., Nakamura, T., Medina-Filho, H.P., Carvalho, L.C., Fazuoli, L.C. and Costa, W.M. (1984). "Coffee", in Ammirato, P.V., Evans, D.A., Sharp, W.R. and Yamada, Y. (eds.) Handbook of Plant Cell Culture Vol. 3: Crop Species, MacMillan Pub. Co., New York.

Spiegel-Roy, P. and Vardi, A (1984). "Citrus", in Ammirato, P.V., Evans, D.A., Sharp, W.R. and Yamada, Y. Handbook of Plant Cell Culture, Vol. 3: Crop Species, MacMillan Pub. Co., New York.

Stakman, E.C., Bradfield, R. and Mangelsdorf, P.C. (1967). Campaigns Against Hunger, Harvard University Press, Cambridge, Massachusetts.

Standke, K.H. (1987). "The political process in the implementation of technology assessment", ATAS Bulletin, 4, October, pp. 14.

Tisserat, B. and Galleta, P.D. (1987). "In vitro culture of lemon juice vesicles", Plant Cell Tissue and Organ Culture, 11, 81-95.

Tudge, C. (1988). Food Crops for the Future: The Development of Plant Resources, Blackwell, Oxford.

Vasil, I.K. (1988). "Progress in the regeneration and genetic manipulation of cereal crops", Bio/Technology, 6, 397-402.

Villalvazo, J., Ramirez, F.J. and Guellmann, K.A. (1985). "Estudios técnicos y económicos para la instalación de una planta de celulosa y paper a partir del henequen en el Estado de Yucatán, in Cruz, C. et al. op cit.

Villaseñor Luque, A. (1987). Caficultura Moderna en México, Agrocomunicación Saenz Colin y Asociados, Chapingo.

Wad, A. (1987). "Technology assessment: A review of institutional approach", ATAS Bulletin, 4, p. 10.

Webber, I.L. (1980). "Social organization and change in modern Yucatan", in Mosley, E.H. and Terry, E.D. (eds.) Yucatan a World Apart, University of Alabama Press, Alabama, U.S.

Woodroof, J.G. (1979). Coconuts: Production, Processing, Products, Avi Publishing Company, Westport, Connecticut, pp. 92-125.

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. Bhattu December 1975
WP. 23	The effect on employment of change in technology in tea and coffee plantations in India. Part B - Tea	I.Z. Bhattu December 1975
WP. 24	Technologie et emploi dans le secteur de la construction en Tunisie	P. Perchiou and R. Lakhoua 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 interdependence 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 in the dairy and sugar industries: Contrast between Mexico and the United States	Gerardo Otero
January 1989
WP. 193	Biotechnology trends: A threat to Philippine agriculture?	Saturnina C. Halos
January 1989
WP. 194	Biotechnology and farm size in Kenya	L.P. Mureithi and
B.F. Makau
January 1989
WP. 195	New biotechnologies for rural development	P. Bifani
January 1989
WP. 196	L'absorption des technologies et l'organisation dans la production dans le secteur informel des fabrications métalliques à Quito (Equateur).	G. Farrell
January 1989
WP. 197	Options technologiques dans la branche des fabrications métalliques du secteur informel à Lima (Pérou).	E. Chavez
January 1989
WP. 198	Technology adaptation and innovations in the informal sector of Dhaka (Bangladesh).	N. Khundker
January 1989
WP. 199	The Socioeconomic impact of agricultural biotechnology on less developed countries	Harold H. Lee and
Frederick E. Tank
January 1989
WP. 200	Advanced plant biotechnology in Mexico: A hope for the neglected?	Amarella Eastmond
and Manuel L. Robert
February 1989