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SUSTAINABLE AGRICULTURAL DEVELOPMENT: THE ROLE OF INTERNATIONAL COOPERATION

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Will biotechnology alleviate poverty?

POVERTY CHARACTERISTICS AND TRENDS

The greatest numbers of the poor, including the very poorest, live almost entirely in rural areas. Therefore it is not surprising that agriculture is the main source of income of the *world's* poor (World Bank, 1990) and agricultural growth has a decisive influence on the evolution of poverty (Singh and Tabatabai, 1990). The rural poor belong to wage labour or marginal farmer households, poverty resulting as much from low returns as from unemployment and under-employment. Their number has increased from 767 million in 1970 to 850 million in 1985 (Singh and Tabatabai, 1990.).

World food crop production grew half a per cent faster than growth in population over the last two decades. Despite the positive margin, the absolute number of under-nourished in the Third World increased from 460 million in 1969–71 to 512 million in 1983–5 (Singh and Tabatabai, 1990). This increase cannot be attributed to variability of food production (ILO, 1990). The demographic projections suggest that demand for food could grow by 3 to 4 per cent per annum in the coming years (Pronk, 1991).

Hunger results from the inability of poor countries, poor families and poor individuals to purchase sufficient quantities of food from available food supplies. Biotechnology could make a contribution to poverty alleviation if it is accompanied by widespread gains in the poor's purchasing power by improving labour absorption without sacrificing growth.

The Third World agricultural labour force is projected to increase at 0.8 per cent per annum until the year 2000 (Singer, 1990). Furthermore, a yield plateau has been reached for major crops, particularly for rice (Barker, 1989). The green revolution rice remained unchanged around the yield potential of the IR-8 rice variety released in 1984 (Lipton and Longhurst, 1989). Therefore future yield gains critically depend on what biotechnology has to offer.

BIOTECHNOLOGY AND POVERTY-RELATED ISSUES

Biotechnology consists of a cluster of commercial techniques which use living organisms to make or modify a product, including techniques for improving the characteristics of economically important plants and animals and for

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developing micro-organisms which act on the environment. This paper also deals with micropropagation (tissue culture) techniques often labelled 'second generation' biotechnologies.

Given the time-frame for the release of many of these biotechnologies for crops of importance to the Third World (Table 1), forecasting of the probable impact on poverty alleviation is based on *ex ante* assessment to help influence research in a pro-poor direction. *A priori* deductive reasoning is used to match specific biotechnology breakthroughs in industrialized countries with the prevailing socio-economic context of developing countries to assess likely impact of new technologies on Third World poverty. This is supplemented by hypothesis testing when possible. The paper analyses both the pro- and anti-poor features of current and future biotechnology developments. The poverty-related issues are described below.

Will *transgenic* plants (containing a foreign gene) and genetically-engineered microbes be potentially more scale-neutral at the farm level than the green revolution and mechanical innovations? Will the cost-reducing or output-enhancing potential of biotechnologies be more beneficial to small farmers?[1] Do resource-saving agricultural biotechnologies depress GDP and reduce aggregate employment? Would the newly emerging biotechnologies reduce previously uncontrollable production variances in the agricultural sector?[2] This is of concern to the risk-averse, resource-poor small farm sector.

TABLE 1 *Availability of new biotechnologies for selected Third World crops, 1989*[a]

Crop	New diagnostics[b]	Rapid propagation systems[c]	Transformation systems[d]	Regeneration systems[e]	Time-frame for commercial applications (years)
Banana/Plantain	+	+	–	+	5–10
Cassava	+	+	–	–	5–10
Cocoa	+	–	–	–	>10
Coconut	+	–	–	–	>10
Coffee	+	+	–	+	5–10
Oilpalm	+	+	–	–	>10
Potato	+	+	+	+	0–5
Rape-seed	+	+	+	+	0–5
Rice	+	+	+	+	0–5
Wheat	+	+	–	–	>10

Notes: [a]Source: Persley (1989, p. 23, Table 3.1).
[b]Availability of new diagnostics for pests or diseases based on the use of monoclonal antibodies or DNA probes.
[c]Availability of rapid propagation systems to allow the multiplication of new varieties.
[d]Availability of transformation systems to enable new genetic information to be inserted into single plant cells.
[e]Availability of regeneration systems to enable single cells to be regenerated into whole plants, after transformation.

The paper deals with changes in labour intensity in agriculture, structure and stability of rural employment, and the impact of biotechnology on the rural labour market. The magnitude and skill composition of jobs created and the non-farm employment generated through linkages to laboratories and to marketing and crop processing are analysed. Can biotechnologies be specifically designed and deliberately released to alleviate rural poverty? Several biotechnology developments have affected the international division of labour through disruptions in global trading patterns. What categories of rural workers and producers are affected? Finally, are all external biotechnology developments anti-poor? The related issue of improving Third World countries' access to pro-poor, but patented, biotechnologies is also taken up.

CROSSING THE YIELD FRONTIER

One traditional biotechnology in China, 'Shan Yu 63', which resists the rice blast disease, increased output by 4.7 million tonnes (valued at 1.9 billion yuan) in 1987 and saved 100 million yuan on chemical pesticides, producing a total return of 2 billion yuan (Yuanliang, 1989). A return of 15.7 yuan is obtained from 1 yuan of investment in biofertilizers for wheat. Breakthroughs in cellular engineering included important cereal crops in addition to non-food crops. Genetic material from Sui Yan wheat straw created engineered

TABLE 2 *China: output gains from cellular engineering on major crops*[a]

Crop	Type of cellular engineering	Crop variety	Sown area (ha) in 1988	Increase in yield
Wheat	Chromosomal engineering	Nos 4, 5, 6 Xiao Yan	2 000 000	900 000 tonnes
Wheat	Culture of pollen haploid cells[b]	No. 1 Jing Hua	70 000	15–20%
Rice	Pollen haploid	Xin Xiu, Wan Gen 959, etc.	170 000[c]	About 10%
Rice	Pollen haploid	Nos 8, 9 Zhong Hua	70 000[c]	15–20%
Rice	Marker rescue	No. 1 Hu Yu	3 000[c]	15%
Potatoes	Tissue culture		70 000[d]	Over 50%
Sugar-cane	Tissue culture		4 000	Over 50%
Tobacco	Pollen haploid		10 000	Over 50%
Banana	Tissue culture		100 000 test-tube seedlings	Over 50%

Notes: [a]Source: Yuanliang (1989).
[b]Pollen and ovules have half the number of chromosomes present in all other tissues of a plant. By chemical treatment this number can be doubled so that plants generated from these cells have two sets of identical chromosomes and therefore identical genes. These homozygous plants are very useful in searching for mutants and for breeding.
[c]1985.
[d]1984.

wheat to resist drought, hot wind and diseases (Table 2). The total area sown (in ten provinces of China) is 2 million hectares, increasing yields by 900 000 tonnes. The area under pollen haploid rice, wheat and tobacco was 466 700 hectares between 1981 and 1985.

The new biotechnology in potatoes doubled land productivity, labour intensity and profitability and increased labour productivity by 24 per cent in Kenya (Table 3). Its contribution (value added) to national income is twice that of the traditional technology. The relative efficiency (value added as a proportion of gross output) is higher for the adopters. Nitrogen fixing biotechnologies could increase per hectare maize yields by 0.5 tonnes, that is, 26 per cent on 5.2 million hectares on small farms in Mexico. While national output would increase by 21 per cent, Mexican farmers' income would in-

TABLE 3 *Biotechnology and farm size: potato and tea in Kenya, 1987*[a]

Key Indicators	Potato farms (Number = 33) Biotechnology (BT)	Traditional technology (TT)	Relationship to farm size	Tea farms/estates (Number = 39) Relationship to farm size (biotechnology only)
Labour productivity (gross output/ha) in shillings)	33,210	16,382	Inverse for BT and TT	Inverse
Labour intensity (work-days/ha)	301	144	BT: unclear TT: inverse	Unclear
Labour productivity (kg. work-day)	124	100	Positive for both BT and TT	Positive (sh/work-day)
Labour's factor share (wages as % of value added)	27	23	Positive for both BT and TT	Positive
Capital use				
sh/w-day	3	3	Inverse for both	Positive
sh/ha	867	426	BT and TT	Positive
Intermediate inputs (sh/ha)	3,553	3,008	Inverse for both BT and TT	Inverse
Value added as a proportion of gross output (%)	89	82	BT: positive TT: inverse	Positive
Profitability (gross output minus operating costs in sh/ha)	20,816	9,916	Inverse for both BT and TT	Positive
Income ratio[b]	8	4	—	3 (small farms[c]) 2 (large estates[d])

Notes: [a] Source: calculated from data in Mureithi and Makau (1991).
[b] Ratio of income of the 30 per cent of richer farmers to income of the 70 per cent of poorer farmers.
[c] Up to 3 ha.
[d] Over 20 ha.

crease by 55 per cent (Gilliland, 1988). This limited evidence offers hope for overcoming the present yield barrier with biotechnology.

BOOSTING PURCHASING POWER

The probable impact of biotechnology on the level and pattern of rural employment is analysed below.

Labour absorption in agriculture

Advanced biotechnologies may lead to a saving in labour use for chemical means of plant protection (Ahmed, 1991). Micropropagation in Mexico need not cause labour displacement in citrus cultivation as this would be compensated by more intensive labour use in weeding, pruning, irrigation and harvesting. In Kenya the doubling of labour intensity per unit of land was due to more labour being needed for ridging before cultivating micropropagated potatoes and in Malawi for nursery and planting operations.

Seasonality and structure of employment

Through biotechnologies applied to crops, animal feed and milk production, an indirect and steady source of employment could be created by linkages to juice processing (Mexico), poultry production (Nigeria), coffee, henequen, tequila and dairy industries (Mexico) and the tea industry (Kenya). Underemployment in the south-eastern region of Mexico could be reduced by applying advanced plan biotechnologies (APB)[3] to create and widen crop varieties and prolong the growing season, and by increasing harvests (Ahmed, 1991). Agriculture labour released by APB is absorbed in new and sideline activities, with a change in social organization of delivering these services in China (Yuanliang, 1989). Similarly, increased labour use in Malawi and Kenya was due to structural adjustments in new farm practices for APB.

Employment linkages

The chemicals used in rural areas are not produced there. Over 40 per cent of the fertilizers are imported by developing countries from industrialized countries. Fertilizers are among the most capital-intensive products (Johnston and Kilby, 1975). A large plant can cost between US$300 and 700 million (Doyle, 1985). Reducing fertilizer use should not cause labour displacement.

Biotechnology use requires blending of workers with 'low-tech' skills engaged in traditional agricultural work with 'highly skilled' technicians involved in the generation of advanced biotechnologies (Ahmed, 1991). In Mexico, scientists and technicians produced plantlets cultivated by agricultural labour. In addition to the employment created for the traditional workforce in agriculture, 933 scientists were employed by the Tea Research Foundation of Kenya in 1986 with an income of K704 371 (Mureithi and Makau, 1991). About 512 plant scientists work on cellular engineering in China (Yuanliang, 1989). In Nepal, scientific personnel produce 8 000 to 10 000 potato plantlets per day through micropropagation which are transferred to sandbeds by semi-skilled workers (Rajbhandari, 1988).

Women dominate the micropropagation laboratories in the Philippines (Halos, 1991) and Mexico (Eastmond *et al.*, 1989). They constitute 80 per cent, 74 per cent and 85 per cent of the Philippine Society for Microbiology, Cell/Molecular Biology and Biotechnology Societies, respectively. These were considered low-paid jobs concerned with basic science with limited linkage to industry. Moreover, work in tissue culture laboratories is tedious, requiring patience and perseverance.

Because of the resource-saving character of biotechnological innovations an input–output simulation exercise reveals a series of inter-industry repercussions throughout the economy, the cumulative impact of which may be to depress GDP and aggregate employment (Lee and Tank, 1991).

RURAL LABOUR MARKETS

Wage labour

APB could increase the demand for hired labour (in Mexico and Kenya), boost wages, improve labour's factor share and reduce rural–urban wage differentials. Gross earnings from APB in Kenya compare favourably with wage incomes in a modern-sector job, important for dampening the pace of rural–urban migration.

Displacing female wage labour: worsening poverty

The green revolution (GR) relied on manual labour for weeding, which had the following characteristics (Ahmed, 1991): (1) weeding is one of the most labour-intensive of all agricultural operations; (2) there is a significant increase in the demand for hired labour in weeding (doubled in Sri Lanka); (3) weeding labour doubled or tripled over that of the pre-GR crops (as, for example, in Bangladesh and the Philippines); (4) small GR farmers recorded much higher labour intensity in weeding than larger farmers; and (5) women constituted between 72 and 82 per cent of such labour input. The genetically engineered plants will substitute chemical herbicides for manual weeding, massively displacing women. Therefore genetic engineering will not only introduce a new fixed cost for farmers by forcing them to purchase the herbicide genetically tied to the seed supplied by the same company, but will also strike a colossal blow at the poor.

ENHANCING CROPPING INTENSITY

Multiple cropping, facilitated by early-maturing GR varieties, contributed to greater labour use. Micropropagated potatoes could similarly improve cropping intensity. Since potatoes in most Third World climates take only 40–90 days to grow (compared to 150 days in temperate climates), it can easily be accommodated with current cropping patterns.

Thirty poor countries can already micropropagate potatoes, a major source of food for poor families in Africa and Asia. Indeed, micropropagation has made potatoes the second biggest crop after rice in Vietnam and quadrupled production in China over 30 years (*The Economist*, 13 October 1990). In Vietnam, micropropagation has increased potato yields from 200 tonnes to 8000 tonnes per year on 450 hectares during 1980–4 (Uyen and Zaag, 1985). Yield has increased from 8 tonnes to 18 tonnes per hectare in Nepal (Rajbhandari, 1988). The following reasons make micropropagation a very attractive option: (1) year-round production of plantlets is possible; in one rural valley of Vietnam each family produces up to 150 000 plantlets per year (Walgate, 1990); (2) it saves costs and reduces difficulties of physical transportation of tubers to the fields for planting; (3) by generating plantlets from tissues, a substantial volume of tubers spared from planting can now be eaten; (4) disease-free planting material could reduce production variances from disease, potato being vulnerable to 268 diseases, and late blight can wipe out more than 50 per cent of crop (Manandhar *et al.*, 1988); and (5) while yields benefit landowners, increased cropping intensity also benefits the landless by increasing hired labour demand.

WILL SMALL FARMERS BENEFIT?

As with the GR diffusion process, large farmers are pioneering adoption of APB in Kenya. Economic inducements exist for all categories of farms for adoption of advanced biotechnologies. The Chinese experience provides proof of APB profitability. In Nigeria, escalating costs of vegetative sources of animal feed and the lower relative price of single cell protein (SCP) serves as an inducement. More than half the small-scale growers in Mexico were willing to adopt APB-based disease-free planting material. Although biotechnological innovations constitute variable costs, collecting information on the technology represents a fixed cost. This is an important reason for the continuation of a bias in favour of large farmers (Kinnucan *et al.*, 1989).

Small farmers in Asia adopted the GR technology only after large ones had applied it and raised yields. While large farmers obtained 'innovators' rent', food prices had fallen by the time pooorer, later adopters were ready to sell (Lipton and Longhurst, 1989). Similar experience may be repeated for biotechnology, although with a reduced lag. The farmers in non-GR areas of Asia, often the poorest, gained nothing from the GR. They lost when extra output from GR areas depressed the returns from their meagre output, for example when the extra GR sales from Punjab (wheat) or Central Luzon (rice) pulled down farm-gate prices in impoverished Madhya Pradesh (India) and

Mindanao (Philippines) respectively (Lipton and Longhurst, 1989). Through its potential for less favoured areas, biotechnology may help redress this disparity.

REDUCTION IN FARMING COSTS: A BOON FOR WHOM?

Nitrogen fertilizers account for 75 per cent of agricultural production costs in Brazil (InterAmerican Development Bank, 1988) and 60 per cent of the energy costs of wheat production in India. Fertilizers and pesticides constitute over 80 per cent of costs of production of GR rice in Thailand and wheat in Europe (*The Economist*, 1987). Biotechnology breakthroughs in nitrogen fixation would certainly reduce costs of farming.

In Mexico, micropropagated flowering plants can be produced at half the cost of the imported ones, even after 60 per cent profit. Similar comparative advantages exist for micropropagated *tequilina* (Eastmond *et al.*, 1989). Commercial micropropagation of orchids is insufficient, requiring imports into the Philippines, although prices charged locally are still too high for small farms (Zamora and Barba, 1990). Imported certified potato seed in Nepal resuls in 40 to 60 per cent higher production cost for micropropagation (Manandhar *et al.*, 1988). Domestic micropropagation could reduce costs from Nepalese Rupees 1.5 to about Rupees 0.30–0.50 per plantlet (Rajbhandari, 1988). Cost of producing one pot of micropropagated potato is two-thirds the cost of one seed tuber in Vietnam (Uyen, 1991).

Biotechnology's protection of crops from insects is more economic compared to chemical alternatives. One species accounts for 40 per cent of all soybean crop losses caused by insects in Brazil. An insect-destroying virus introduced on 11 000 hectares during 1983–4 led to about 75 per cent savings in the cost of protecting soybeans, as compared to the cost of chemicals (InterAmerican Development Bank, 1988).

DESIGNING BIOTECHNOLOGIES FOR POVERTY ALLEVIATION

This section demonstrates how exactly biotechnologies could be designed by scientists to launch a planned assault to solve location-specific constraints responsible for impoverishment. The orange leaf rust disease ravaging coffee cultivation in Mexico has threatened the survival of the small growers. Chemical means of control is beyond their reach. Application of APB to supply disease-free or disease-resistant plant materials will not only save but expand the employment opportunities of these producers and of the large body of hired labour, and generate indirect employment through its linkage to the coffee industry and to the micropropagation laboratories and nurseries (Eastmond and Robert, 1991).

The plant *tequila agave* takes nine years to grow in Mexico to a mature stage before it can be utilized. Some 12 million plantlets are required to replenish existing stocks.[4] Some 6000 small contract growers who supply the large agro-industrial companies with the raw material will stand to benefit from rapid micropropagation (Eastmond *et al.*, 1989). Linkages to the tequila drink industry will result in additional and more stable employment.

Combating malnutrition

The application of SCP could help alleviate protein malnutrition in general and boost animal protein intake by the Nigerian protein-deficient population (Okereke, 1991).[5] The economic climate is favourable for its acceptance in Nigeria because: (1) the income elasticity of demand for poultry products is higher than that for beef; (2) the supply–demand projections reveal an excess demand for poultry products; (3) relative prices of other sources of poultry feed are higher and increasing; and (4) the ban on the import of poultry products and feed provides the protection needed.

Between 1979 and 1987, the import of soybeans and protein meal as sources of animal feed increased by 433 per cent to 516 per cent in Venezuela (Martel, 1990). The abundant supply of natural gas in Venezuela could easily be harnessed to produce SCP. Cuba has already established 13 SCP plants based on cane-molasses (InterAmerican Development Bank, 1988).

Milk for the thirsty

In Mexico the bovine somatotropin (BST) technology could reduce the daily deficit of 12.5 million litres of milk and make it more accessible to the population (37 per cent of whom currently consume only 14.5 per cent of the available milk supply). It increases milk production in cows by 10–25 per cent. This is like having extra milk without extra feed. Employment would increase in the production and processing of milk and the feed industry, all of which are concentrated in a few hands (Otero, 1991a). BST also holds prospects for Pakistan. Despite having three and a half times as much pasture as Wisconsin and over one and a half times as many dairy cows, Pakistan produces only a quarter as much milk. Pakistan's cows are only 15 per cent as efficient as Wisconsin's. Pakistan spends $30 million on milk imports each year (*The Economist*, 13 Janury 1990). Most astonishingly, milk produced per day could be five times higher for BST-treated cows in Zimbabwe (Kirk, 1990).

Returns over variable cost could be 26 per cent for dairy farmers using BST (Otero, 1991a). With assumptions of milk prices and costs, if BST can increase milk production by 15 per cent, a farm with 500 cows could make an extra $82 000 profit per year in the United States (*New Scientist*, 24 March 1988). There should now be less concern for consumer safety since the US Food and Drug Administration and a team of US doctors have announced that BST causes no changes in milk composition of any practical importance to consumers (*Chicago Tribune*, 1990 and *International Herald Tribune*, 1990).[6]

Four major manufacturers of BST argue that its cost of less than one dollar a day per cow would make it scale-neutral (Schneider, 1989). This would be facilitated by the expanding global (approaching $1 billion annually) and international ($100–$500 million annually) markets (Schneider, 1989, UNDP, 1989).

GENETIC ENGINEERING FOR THE POOR

Some of the fragmented and widely scattered information on primarily single gene-based genetic engineering breakthroughs assembled reveals some trends (Ahmed, 1991). The private sector corporations dominate genetic engineering research and their eyes are on agronomic traits and on crops which promote markets for their seeds and/or agrochemicals. These also concern crops of importance to industrialized countries as it is difficult to police patency infringements in Third World countries. Developing countries generally do not have patent laws. The private industry cannot recover revenue through royalties and licences.

The private sector accounts for two-thirds of total global funding (US$4 billion) of biotechnology research, and large chemical multinational companies spent 50 per cent of the total R&D budget on biotechnology. They spent $10 billion over the last decade to buy up seed companies for marketing their own biotechnology products (James and Persley, 1989). After 2001, 75 per cent of all major seed will be based on biotechnology (*McGraw Hill Biotechnology*, 1989). The cost of seeds as a proportion of total cost of wheat in Europe could rise from 20 per cent to 50 per cent at about that time (*The Economist*, 1987).

The possible socio-economic impact of the *transgenic* plants and microbes could involve the following: (1) Pest and disease resistance and drought tolerance will reduce output variance, important for risk-averse farmers; together with breakthroughs for nitrogen fixation this will reduce farmers' costs of production; further research by Cornell University Boyce Thompson Institute for Plant Research which has discovered a bacterium that can fix nitrogen without depending on the plants for energy should be encouraged (*Genetic Engineering News*, 1989); (2) production of less thirsty crops will increase labour absorption through area expansion and multiple cropping; (3) lower labour requirements in pest and disease control may be made up by overall increases in labour use in other new operations; (4) herbicide resistance will directly displace labour for weeding, particularly for the vulnerable groups; (5) prolonged shelf life of freshly harvested agricultural produce will help the poor faced with inadequate marketing infrastructure; (6) genetic engineering breakthroughs in (1) and (2) above will help compensate for inadequacies of extension services and delivery failures; (7) genetically engineered microbes may benefit the small farmers if these spill over to the poor neighbours' plots and fix nitrogen there or protect the crops from pests and diseases there; a rough comparison of chemicals with microbial controls shows the clear economic and safety advantages, although costs need to be further reduced and effective means of dispersing the microbes would make their use feasible for smallholders (Bunders, 1990); (8) the major obstacles to the Third World countries and poor farmers' access to socially beneficial biotechnologies are the legal and financial barriers associated with the proprietary rights over these technologies through patents; moreover, increasing research partnership between industry and the academics tends to diminish Third World countries' access to technology previously available freely as a public good; (9) Third World countries could gain from increased wool production through genetically-engineered pasture crop (saves on grazing land) and from cost reduction through biotechnologies which substitute for mechanical wool harvesting technologies.

USING THIRD WORLD BIOTECHNOLOGY CAPABILITIES

The 'second-generation' biotechnologies are within the scientific and financial reach of Third World countries. A fully equipped laboratory might cost US$250 000 (Lipton and Longhurst, 1989). More astonishingly, a tiny micropropagation facility in a farming household costs only US$354 to produce 200 000 plantlets annually in Vietnam (Ministry of Agriculture and Food, Vietnam, 1987).

Micropropagation is already applied to potatoes in 30 poor countries. Singapore and Brazil produce coffee plantlets on a large scale (*Biotechnology and Development Monitor*, 1990). Micropropagation capabilities were noted for Malawi, Nepal, Vietnam and Kenya. Unfortunately, this capacity used for non-food crops meets the needs of the commercial large-farm sector in the Philippines, Mexico and India (Mani, 1990; Zamora and Barba, 1990; Eastmond *et al.*, 1989).

Tissue culture in Japan could produce 3 billion rice seedlings from a single seed in about six months. It saves seeds (releasing more grains to feed the hungry) and supplies vastly more seedlings to be planted by the countless unemployed hands in the densely populated areas of the Third World. In labour-scarce Japan robots are being sought to meet the intensive labour demands for root separation of seedlings grown by the new technique (UNIDO, 1989). On the other hand, tissue culture in California could turn sour for Third World grape producers if they are denied access to it (*Scientific American*, 1991).

THE NEW INTERNATIONAL DIVISION OF LABOUR : WHAT HAPPENS TO THE POOR?

By the end of the decade, biotechnology will affect developing country exports worth US$66 billion (Table 4). These countries may lose annually $10 billion of their export income (Kumar, 1988) with serious repercussions on the international division of labour. While 90 per cent of the sugar internationally traded came from developing countries in 1975, it declined to about 67 per cent in 1981 (Otero, 1991a). Sugar imports by developed countries declined from 70 per cent to 57 per cent during the same period. World consumption of high fructose corn syrup (HFCS) accounted for only 1 per cent of total sweeteners in 1975, but rose to 6 per cent in 1985 (Wald, 1989). A total of 34 soft drink manufacturers in the US have switched to the immobilized enzyme technology. In consequence, sugar exports from the Philippines declined from $624 million in 1980 to $246 million in 1984. In the Caribbean the decline of sugar export to the USA was similar. This was accompanied by a crash in sugar prices from US cents to 63.20 per kg. in 1980 to US cents 8.36 in 1985 (Panchamukhi and Kumar, 1988). The livelihood of over 50 million workers engaged in the sugar industry of Third World countries were affected by the decline in exports (ibid.)

Replacement of vanilla flavour by biotechnology products threatens 70 000 small farmers in Madagascar, which could lose US$50 million of its annual export earnings (Mushita, 1989). Comoros will be similarly affected (Junne, 1990). A Californian company commercially produces vanilla plantlets through tissue culture for the lucrative annual flavouring market worth US$200 million (*New Scientist*, 1991). The lower cost of tissue culture compared to the traditional vanilla extract makes it more profitable. Cacao, the second most important agricultural commodity in the Third World, faces similar threat. Africa accounts for nearly 60 per cent of the world production of cacoa. Small cocoa producers in Cameroon, Ghana and Côte d'Ivoire will be affected by the biotechnology developments in the Swiss-based company, Nestlé (Hobbelink, 1989). Patent applications have been made by Kao Corporation of Japan for genetically engineered enzymes for making cocoa butter substitutes (Svarstad, 1988).

Biotechnology research in Germany could produce a substitute for coffee (Otero, 1991b). Third World countries account for almost the entire world's coffee exports (US$10 to 50 billion each year). Apart from the adverse impact on the balance of payments of Colombia, Burundi, Uganda, Rwanda and Ethiopia, the livelihood and jobs of 500 000 small producers in Rwanda and another 650 000 in Indonesia would be threatened (*Biotechnology and Development Monitor*, 1990).

The next oil crisis: who are the victims?

Biotechnology converting plant oils into structural lipids or tailored fats will affect the market shares of 11 vegetative oil crops traded by the Third World (Ruivenkamp, 1991). Biotechnology will dramatically increase the market for castor, palm and groundnut oil and reduce eight others (Kumar, 1988). While coconut is the source of only 2 per cent of the world's oils and fats market, the Philippines alone supplies 80 per cent of it. Decline in its export would affect 15 million Filipinos, who are poorer than the rest of the farming population (Halos, 1991).

IS AGRARIAN REFORM STILL IMPORTANT?

Inverse relationships between farm size and productivity, both under the traditional and the new biotechnology, for potatoes and tea are observed in Kenya (Table 3) and Malawi. Small farms as compared to large ones, make a larger contribution to national income, extract higher levels of profit and demonstrate

TABLE 4 *Biotechnology's impact on Third World exports by type of biotechnology and time-frame*

	Micropropagation techniques		Transgenic plants	
Time-frame for routine use	Value of exports (US$ billions)	Exports affected (number of developing countries)	Value of exports (US$ billions)	Exports affected (number of developing countries)
Up to 1995	20.9	Coffee (28), Bananas/ plantains (16), rice (6), rubber (5), tobacco (2), vanilla (2), cassava (1), potatoes (1)	6.4	Rubber (5), tobacco (2), maize (1), potatoes (1), tomatoes (0)
1995–2000	21.2	Sugar-cane/sugar-beet (16), cocoa (15),tea (4), soyabeans (3), oil palm (3), wheat (3), maize (1), sunflower (1), pineapple (0), sorghum (0), barley (0), sweet potatoes (0), yams (0)	17.5	Sugar-beet (16), cotton (15), bananas/plantains (16), rice (6), soyabeans (3), cassava (1), sunflower (1), barley (0), rape-seed (0), sweet potatoes (0), yams (0)
Year 2000 and beyond	3.4	Cotton (15), coconut (10), rape-seed (0), millet (0)	21.7	Coffee (27), sugar-cane (16), cocoa (15), coconut (10), tea (4), oil-palm (3), wheat and flour (3), pineapple (0), sorghum (0), millet (0)

Source: UNCTAD (1991).

stronger linkages to agricultural input suppliers. A small farm-based development strategy would increase output and prevent worsening income inequality without sacrificing employment.

With the application of APB, labour's factor share increases in Malawi and Kenya. This share is already high in Mexico. However, the past trend of increasing social differentiation will be accentuated in Mexico through limited mobility across occupational class structures (Eastmond and Robert, 1991) and in Kenya (increase in the concentration ratio), unless essential agrarian reforms are adopted. The advent of biotechnology into an agrarian system in which land is unequally distributed will tend to reinforce the existing inequality (Table 3). The Kenyan evidence with biotechnology represents a close parallel to the experience of inequality created by the green revolution in Asia, although it is likely to be less acute.

NOTES

[1]Farmers are assumed to select on the cost curve the least-cost combination of inputs to produce a given level of output. Technological change should reduce the use of farm inputs at any relative price so that those scarce resources can be reallocated to other uses.

[2]Insect- and disease-resistant biotechnologies counter some of the stress and pathological losses associated with disease and insect infestations. The new biotechnologies could reduce the previously uncontrollable fluctuations in production.

[3]APB will be used henceforth to signify micropropagation techniques.

[4]The plant is used to produce high-quality spirits, particularly tequila, an important Mexican export.

[5]SCP are dried cells of micro-organisms which are grown in large-scale culture systems for use as protein sources in human and animal feeds. Micro-organisms can develop between 100 and 1000 times more quickly than a plant or an animal.

[6]It was feared that BST could transfer from the milk into the blood, producing hormonal and allergic effects. It was also considered as an unnecessary and cruel way of squeezing out more milk from the cow to pour into overflowing milk lakes in the industrialized countries.

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DISCUSSION OPENING – MARCO FERRONI*

I enjoyed reading Dr Ahmed's review of some of the key issues relating to biotechnology and poverty alleviation. He discusses yield enhancement, employment and labour market effects, scale neutrality, the challenge of meeting the needs of the poor, the problem of private sector control over world genetic resources, and the replacement of traditional export crops by synthetic substitutes. I did feel, however, that a clear answer to the basic question of whether biotechnology will alleviate poverty was lacking. Dr Ahmed certainly implies that the potential exists for biotechnology to do much good, though this is qualified. There are considerable uncertainties regarding the pace of application and others relating to distributional consequences. Furthermore, there are some potential applications (notably the production of synthetic substitutes) which are decidedly anti-poor, or at least against the interests of developing countries. If this is a correct interpretation of the paper I would declare myself in agreement with its main thrust. To substantiate this view, I would like to discuss four points not covered (or only partially covered) by Dr Ahmed.

In setting out to promote pro-poor technological change (regardless of whether or not it has a biotechnology component), decision makers and their advisers need to:

(1) identify the poor and their technology needs as consumers, labourers, and producers, bearing in mind that in this context the focus needs to be on absolute poverty;
(2) reflect on what we know about the distribution of benefits from technological change in agriculture;
(3) establish criteria for using technology and associated delivery systems to help the poor; and
(4) address the institutional, managerial and legal challenges which may hamper the generation and adoption of agricultural technology capable of helping the poor.

First, agricultural technology can help alleviate poverty if it leads to a reduction in the real price of food staples, an increase in employment and earnings, and an increase in the level and stability of yields. Thus the patterns of consumption, agricultural employment and farm production of the poor must be analysed. Location-specific work on these topics will yield information on the crops and livestock activities which may be candidates for productivity improvement. An issue which should be addressed is whether the poor, in a given context, should be helped as farm producers, as workers or as consumers. It is as well to remember that investments geared to the development of yield-enhancing technology for resource-poor smallholders may have opportunity costs. There may be a trade-off between equity and efficiency in the allocation of resources to agricultural research. Other approaches to poverty

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reduction, including public works, migration away from marginal areas, and better health and education services, may be more cost-effective.

Regarding the distribution of benefits from technological change many factors have to be considered (Binswanger and Von Braun, 1991). Under conditions of inelastic demand, consumers gain from technological change which engenders an expansion in the supply of commodities they use. However, consumers in the Third World do not benefit when products are mainly exported, unless added production for export causes favourable general equilibrium effects. Producers gain from technical change when demand is elastic, which occurs when new markets (including export markets) are opened up. When demand is inelastic (the usual condition for domestically consumed food) they may gain or lose, depending on how fast costs decline relative to prices received. Thus, if producers are net buyers of food (a frequently encountered condition among smallholders), their gains as consumers may outweigh their gains or losses as producers. Labourers gain if technical change leads to a net increase in the demand for hired labour, or to an increase in employment due to growth linkages.

This simple framework is useful for an initial assessment of the required provision of pro-poor agricultural technology. Since consumers stand a good chance of gaining from technical change, as long as it occurs in the right commodities, the focus must be on producers and labourers. Technology for resource-poor smallholders should be *input-extensive* (stress-resistant varieties, which do not require ancillary chemical inputs, are a case in point). It should focus on 'orphan crops' (a term used in the paper by Collinson at this Conference), particularly in Africa (cassava, yams, plantains, coarse grains) and on the less well endowed agro-climatological areas. It should facilitate diversification to enable producers to maintain their share of the gains from innovation and to raise the demand for labour, and it should be accompanied by programmes to speed up adoption (agricultural extension, credit, infrastructure). Land improvement programmes can play an important role in raising the demand for labour, as well as enhancing the future productive base.

Biotechnology would appear to offer a number of potentially useful avenues which meet the pro-poor condition. Possibilities (and in some cases realities) mentioned by Dr Ahmed include tissue culture to produce disease-free planting material, genetic engineering for pathogen and pest resistance, and genetic manipulation to raise cold tolerance or, in the potato, to reduce high temperature susceptibility. The main benefit, however, is likely to be capability to raise the efficiency of conventional plant-breeding programmes. That has been mentioned on a number of occasions at this Conference.

This brings me to my last point about institutional, managerial and legal challenges which I would like to address from the point of view of needs in Sub-Saharan Africa. Caveats about the possible trade-off between equity and efficiency notwithstanding, there is a strong consensus among analysts that 'significant reorientations towards neglected areas and economically weak groups are needed to bring major social and economic gains to the rapidly growing numbers of poor Africans' (Gnaegy and Anderson, 1991). However, this has not crystallized into a shared vision and effective long-term programmes and alliances between donors, international centres and national governments, to raise the dismally low performance of African research institutions. Facing the legal challenges of patenting technical advances in developed countries also requires strong institutions working in favour of the developing world.

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