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SUMMARY OF THE STUDY ON

BIOTECHNOLOGY IN THE ESCWA MEMBER COUNTRIES
Sectoral Issues and Policies

United Nations
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EXPLANATORY NOTES

NAGEL was turned into the Agricultural Genetic Engineering Research Institute (AGERI) in 1992 (15,19).

The world's highest potato yields are recorded in Belgium and Luxembourg, amounting to 49 tons per hectare in 1993 (8d).

The term "small company" refers to a workforce of 20 persons or less.

Introduction

During the last decade, developments in the biological sciences culminated in the capacity to transform life. Futuristic scenarios with ever-green deserts, full of plants capable of shutting off their metabolism to withstand extreme environmental stress, are expected to become a reality in the not too distant future. Unicellular organisms may be genetically changed and cultivated in large batches in order to mass produce rare food ingredients and pharmaceuticals. A cure for cancer may be closer thanks to advances in monoclonal antibody technology. In short, the promise of biotechnology is expected to exceed its present impact not only in the industrialized countries but all over the globe. It is not so much a question of whether developing countries will be affected but more a question of when this will take place and in what way.

To help the member countries of ESCWA to prepare for the anticipated impact of biotechnologies, the study on Biotechnology in the ESCWA Member Countries: Sectoral Issues and Policies, of which the present paper is a summary, provides an account of recent trends of direct interest to the region.

As the pharmaceutical industry is focused on satisfying the market needs of the high-income economies, diseases that are innate or more dominant in developing countries have tended to receive less attention. It is therefore in these countries that appropriate biotechnologies must be developed for combating diseases, such as leishmaniasis, that are endemic to the developing world, and to some ESCWA member countries.

The food-processing industry is yet another sector that needs region-specific biotechnologies. Fermentation of food crops like dates and olives, which enjoy comparatively large market sizes in the ESCWA region, does not receive much international attention. Local research on bioreactors is therefore needed here to support the development of new processes and improve the performance of more established ones for the benefit of the food industry in the region. Bioreactors also play a key role in the production of enzymes used in the beverage, detergent and leather industries. Although these sectors are well developed in the ESCWA region, little research activity has been reported.

Despite the importance of the health and industry sectors, the study puts most emphasis on agrobiotechnologies for two reasons. First: research on plants for crop improvement directly relates to specific ecological conditions predominant in the ESCWA region, whereas biotechnology applications for industry and human health are more universal in nature. Secondly: preliminary data indicate that most biotechnology research activities in the ESCWA member countries relate to agriculture.

The technology for improvement of crops is mainly developed in industrialized countries whereas the genetic input is provided by centres of genetic biodiversity which are mainly located in non-industrialized countries. For instance, in the 1980s, wheat and barley production in the United States of America suffered great losses, caused by an infestation of Russian aphid. No tolerant or resistant varieties of wheat or barley were available in the United States at that time. It was only by incorporating genes from several Middle Eastern strains of wheat, using extensive crop breeding programmes over many years, that the pest was effectively controlled (1). Although no country in Western Asia received compensation for the use of its germ plasm, these countries will have to pay for obtaining seeds of the improved pest-resistant varieties which incorporated genes of that same germ plasm.

Over the past few decades, agricultural production in Western Asia had to struggle to meet the needs of the rapidly growing population. In 1994, total arable lands in the Arab countries amounted to only 4% of the total area (7). ESCWA member countries have become large importers of foodstuffs, mainly because of high population growth rates. An important factor limiting the increase in agricultural production is the critical and complicated problem of water supply and poor soil fertility in many parts of the region. Water problems relate to inadequate groundwater resources, erratic rainfall, waterlogging and salinity. In the Gulf

countries in particular, owing to the depletion of groundwater resources, soil salinity poses an increasing problem for crop cultivation.

Owing to the fact that the region is, overall, a heavy importer of agricultural produce and food commodities, the agricultural sector is given high priority in all government policies of the ESCWA region. The Gulf Cooperation Council heavily subsidizes both inputs and outputs of agricultural production. Because of this, Saudi Arabia recorded the world's strongest growth in agricultural production output in the 1980s and 1990s and has become a major food exporter (9). In 1994, the agricultural production index of Saudi Arabia had reached 506.55 compared with 100 in 1980 (8b). Other ESCWA members, such as Egypt and Yemen, are traditional agricultural countries with the majority of the population involved in cultivation of crops (Egypt: 33%; Yemen: 61% in 1994). Their Governments heavily support agriculture in consideration of the numbers of rural poor in these countries.

Two Arab Conferences on Perspectives of Modern Biotechnology were organized in 1989 and 1993 by ESCWA in partnership with other United Nations organizations, as well as the Higher Council for Science and Technology in Jordan. Both conferences clearly showed that, as mentioned above, most biotechnology research in ESCWA member countries is geared towards agriculture. Therefore, an analysis of agrobiotechnologies in selected ESCWA member countries will provide more insight in analysing the problems faced in biotechnology transfer and development. As a direct follow-up of the recommendations of the Second Arab Conference on Perspectives of Modern Biotechnology the study investigates leading technologies (genetic engineering and plant cell and tissue culture) with the aim of clarifying the opportunities and challenges for the ESCWA region. To avoid generalizations, the study allows for some differentiation in its policy recommendations for the selected ESCWA member countries (Egypt, Jordan, Saudi Arabia and the Syrian Arab Republic) to better cater for their individual situations *vis-à-vis* the impact of biotechnologies.

PART ONE
AGROBIOTECHNOLOGIES

I. GENETIC ENGINEERING OF PLANTS

It is believed that the market for biotechnology-derived plant products will be valued at US$ 12 billion by the year 2000 (13a). Investments in genetic engineering of plants are on the verge of bearing fruit, as the first transgenic crops are available in the market. Transgenic tobacco with increased virus resistance has been commercially cultivated in China since 1992 (2b). The first transgenic food produce, the "Flavr Savr" tomato variety with an improved taste and shelf-life, has been available on the United States market since 1994 (5a). The transgenic tomato was followed in 1996 by genetically engineered maize which harbour Bacillus thuringiensis genes, allowing the crop to produce its own pesticide (i.e. B. thuringiensis toxins) against the European corn borer. In August 1995, the United States Government approved the marketing of transgenic maize seed to start in 1996 (10). The marketing of a herbicide-resistant soybean variety was also scheduled to start in 1996 (14b).

Worldwide, China and the United States are the only two countries where large-scale releases of transgenic plants have been authorized for the purpose of commercialization (2a). In China, genetically modified virus-resistant tobacco has been used in industrial tobacco manufacturing for national consumption since 1992 and the area where virus-resistant tobacco is cultivated now amounts to nearly 1 million hectares (ha), almost 5% of the total area devoted to cultivation of tobacco.

Rough estimates suggest that the development of a genetically modified plant costs about US$ 10 million, of which US$ 1 million is for regulatory expenses; it requires approximately six years to go from the laboratory stage to a commercial product (13b). By comparison, traditional genetic breeding costs between US$ 2 million and US$ 2.5 million, and requires a 6- to 10-year development period (13c). Equipment costs for outfitting a basic plant genetic engineering laboratory are estimated to be at least US$ 600,000. The running costs of such a laboratory are very much dependent on the type of research, the salaries of research personnel, and the cost of maintenance and supplies.

Developments in selected ESCWA member countries

Only some countries in the region have established facilities for molecular biology research (see table 1). Of those countries, Egypt and Kuwait have undertaken genetic engineering research for crop improvement; only Egypt succeeded in genetically transforming a plant by installing virus resistance into potato lines. So far only ICARDA (International Center for Agricultural Research in Dry Areas) has established the use of molecular biology as a supportive tool for plant breeding by developing genetic markers. There are no private initiatives in genetic engineering of plants reported in the region.

The only research institute in Egypt with experience in genetic engineering is the Agricultural Genetic Engineering Research Institute (AGERI), established in 1989. AGERI is part of the Agricultural Research Center (ARC), administered by the Egyptian Ministry of Agriculture and Land Reclamation.

The research objectives of AGERI are mainly aimed at establishing virus-, insect-, and fungal-resistant crops, as well as improving environmental stress tolerance of crops. Another research group aims to increase the nutritional quality of faba bean by isolating and inserting genes encoding for natural storage proteins.

TABLE 1. INSTITUTES IN ESCWA MEMBER COUNTRIES INVOLVED IN PLANT MOLECULAR BIOLOGY RESEARCH

ESCWA member States	Number of institutes
Egypt	3[a/]
Iraq	1[b/]
Jordan	2[c/]
Kuwait	1[d/]
Syria Arab Republic	1[e/]
Total	8

a/ ESCWA, Inter-Agency Task Force Meeting, Biotechnology Applications and Technology Transfer, Survey of Biotechnology Activities in Egypt, mission report on visit to Egypt, 16-21 December 1995, ESCWA secretariat, Amman.

b/ J. Jubrael, personal communication, IPA, Agricultural Research Center, Baghdad, ICARDA Regional Symposium on Integrated Crop-Livestock Systems in the Dry Areas of West Asia and North Africa, Amman, 7 November 1995.

c/ W.M. Owais, Dean, Faculty of Sciences, Yarmouk University, Irbid, Jordan, personal communication, 1996.

d/ A. Sasson, *Biotechnology in Developing Countries: Present and Future,* volume I: Regional and National Survey (Paris, UNESCO), p. 614.

e/ B. Al-Safadi, personal communication, Atomic Energy Commission of Syria, Damascus, 18 February 1996.

Note: Number of institutes per country indicates the minimum number of national research institutions.

In 1992, AGERI achieved an international breakthrough in genetic engineering of potatoes, by regenerating three commercial potato cultivars with a chimeric gene encoding the coat protein of potato X virus, using the Agrobacterium tumefaciens leaf disc transformation method (3c). Other ongoing research activities of AGERI include (18a):

(a) Genetic transformation research on tomatoes, cucurbit, maize and cotton;

(b) Genome mapping of tomato, rapeseed, and Bacillus thuringiensis toxin genes;

(c) Protein engineering of faba bean;

(d) Identification of biotypes of Bemecia tabaci (white fly).

The 16 senior scientists of AGERI have institutional affiliations with six Egyptian universities as well as with various national agricultural research centres. AGERI is collaborating with many universities (Michigan State University, Cornell University, University of California) in the United States through its ABSP (Agricultural Biotechnology for Sustainable Productivity) project funded by USAID (18b).

AGERI has been financially dependent on foreign donors since 1991. UNDP was a major donor in 1991 (US$ 1.5 million (15)), USAID from October 1992 till December 1995 and new USAID funding support was approved for 1996-1997. The Egyptian Agricultural Research Institute (ARC), which administers the project, pays the salaries of staff (15, 19).

In line with its aim to achieve self-reliance and self-financing to mobilize the funds necessary for the running costs of laboratories, AGERI has undertaken some commercial activities (15, 19), such as the sale of DNA (deoxyribonucleic acid) oligonucleotides and ELISA (enzyme linked immunosorbent assay) kits to detect potato viruses (in 1995 approximately 50 kits were sold for 1,000 Egyptian pounds per kit).

Other Egyptian institutes in the process of starting genetic engineering research include institutes at Cairo University and Menufia University. These institutes are much smaller than AGERI in terms of human and financial resources. Like AGERI, Cairo University and the Genetic Engineering and Tissue Culture Center of Menufia University are trying to incorporate Bacillus thuringiensis endotoxin genes into cotton for pest control.

Genetic engineering of plants with the aim of obtaining transgenic plants has not been reported in other countries of the ESCWA region. Only ICARDA is equipped to work on genetic engineering. ICARDA, located near Aleppo, in the Syrian Arab Republic, is the best established plant breeding institute in the region and has worldwide mandates in breeding and germ-plasm conservation of barley, lentil and forage crops and regional mandates for wheat and chickpeas. Biotechnologies used by ICARDA are mainly to support conventional breeding programmes. Biotechnology activities, effectively started in 1992 (29), were initially restricted to the use of genetic markers (RFLP [restriction fragment length polymorphisms], RAPD [randomly amplified polymorphic DNAs], micro-satellites) to assess the genetic diversity of the existing *in situ* and *ex situ* collections of mandated crops.

In addition, ICARDA has conducted a search for genetic markers which can be linked to superior traits such as resistance and tolerance to biotic and abiotic stresses, especially drought. Tissue culture techniques, especially the use of double haploid lines in barley and wheat as well as interspecific hybridization in wheat and chickpeas, are used to support the breeding programme. The total budget for biotechnology research at ICARDA amounted to US$ 1,335,312 in 1994, of which US$ 617,950 was for salaries and employment costs (27). Total staff of the biotechnology laboratory consists of 2 research leaders and 12 research workers. Funding is mainly supplied by the Governments of France and Germany and by the United Nations Development Programme (UNDP). ICARDA has subcontracted some of its biotechnology research to German and French universities, as well as institutes in Egypt (AGERI), Morocco and Tunisia (29b).

II. PLANT CELL AND TISSUE CULTURE

The technology of plant cell and tissue culture evolved from the capacity of a single plant cell to redifferentiate into a new plant. This capacity, or so-called totipotency, is unique to the plant kingdom, and was first described by Haberlandt in 1902. Tissue culture techniques make use of parts of a plant (e.g. leaf, stem, root, meristem) to regenerate a new plant, whereas cell culture techniques make use of a liquid medium containing single plant cells for the same purpose. Cell culture can be used for producing secondary metabolites or artificial seed as well.

The first plant to become fully dependent on tissue culture for its propagation was the orchid. Under natural circumstances, orchids can only germinate by means of a symbiosis with a specific fungus, generally referred to as mycorrhiza. In 1922, Knudsen demonstrated that orchid seed germination was possible on a simple nutrient medium containing minerals and sugars without the help of any fungus (25a).

In the broadest sense, tissue culture is merely an extension of vegetative propagation routinely carried out in a commercial nursery by the rooting of stem cuttings or other plant parts or induction of shooting from root cuttings in a sand culture. Tissue culture has the major advantage of potentially providing hundreds or thousands of identical copies of plants in a small space.

The practical implication of this capacity is that tissues and cells from one superior plant can be used to produce thousands of plant propagules with the same genetic composition. Furthermore, micropropagation of a plant can take place without the delay required for it to bear fruit and seeds. Cell and tissue culture techniques can also be used to induce mutations by the use of selective media or by fusion of plant cells, thereby contributing to crop improvement schemes.

In contrast with genetic engineering, plant tissue culture technology appears to be more within the reach of developing countries. Why is tissue culture more accessible for developing countries? The most important reason relates to the combination of less requirements for investment and research and much better prospects for a direct return on investments. The latter is seen as a crucial factor, especially for the private sector in many developing countries. Time requirements to set up a tissue culture production unit are around 6 - 12 months (30a).

As a result, private companies working on tissue culture have been formed in many developing countries. Any country in which a crop species is a major staple food could profitably invest in a tissue culture laboratory. A capital cost of about US$ 20,000 (in 1993) would permit the import, as tissue cultures, of virus- or disease-free clones developed in research stations abroad and their rapid multiplication, if they proved adaptable to local conditions and acceptable to producers and consumers (3d). The commercial production of virus-free potato seedling tubers is one of the tissue culture techniques most applied in developing countries.

Initial costs for outfitting a tissue culture laboratory for mass-scale virus-free potato tuber production are estimated to amount to at least US$ 185,000, excluding supplies. Major initial costs for virus-free potato production are related to the need for an advanced greenhouse, costing approximately US$ 600,000 for 1,000 m^2 in 1995 (21). Such greenhouses are necessary to avoid virus contamination (transmitted through aphids) of the shoot-tip propagated planting material used to obtain the virus-free mini-tubers. Once established, running costs for a laboratory consist mainly of labour costs and therefore vary from one country to another.

In the case of the Syrian Arab Republic, the General Organization for Seed Multiplication (GOSM) started mass-scale production of potatoes in 1995 and spends US$ 80,000 for running costs (including labour) of the laboratory, through which 200 tons of virus-free potatoes were produced (21). Based on a cost model

of Chu and Kurtz (11f), indicating relative cost components associated with micropropagation, the total running costs of this Syrian PCTC (plant cell and tissue culture) production line would amount to approximately US$ 500,000 per year. On the Syrian market, the average price of potato planting tubers amounts to approximately US$ 0.30 per kg; net sales in 1995 were US$ 60,000. GOSM aimed to produce 7,000 tons of potato tubers using PCTC by the end of 1996, from which a return on investments could be obtained (21). If GOSM had access to the world market, the 200 tons of superior virus-free potatoes would yield US$ 1.2 million to US$ 2.4 million, with net profits of US$ 0.7 million to US$ 1.9 million in the first year of production alone. Of course, such spectacular profits are not to be expected in such a short time-span.

The production of virus-free potato mini-tubers in developing countries would also result in considerable savings in foreign exchange. It has been estimated that Egypt could save up to US$ 30 million per annum by local production (18c). Imports of potato seed tubers in Jordan amounted to approximately US$ 3.4 million in 1993 (33a).

Of all crops grown in Western Asia, date palm may well benefit most from tissue culture to increase production of dates. Plants can be raised from seed, but are then of variable quality, and half their number become unproductive males. The male and female plants cannot be distinguished until they have been grown in the field for several years. Dates are only produced by female plants.

Date palm is the most important crop for Western Asia. The region has been producing 57% of the world total production for a great many years. The more traditional producers of dates include Iraq and Egypt, with more than half a million metric tons of dates produced annually. Over the last decade, Saudi Arabia witnessed the fastest growth in production of dates and has joined this list of major producers.

Date palm plantations are usually established through vegetative propagations and normally consist of one or more clones of mainly female trees. Traditional vegetative propagation is slow: only 20 offshoots are produced per plant during its first five years in the field. On planting the offshoots, only 50% will grow roots and develop into a full plant. This rate has proved inadequate, both for extending date palm cultivation and for replacing ageing plantations or those destroyed by Bayoud disease caused by Fusarium oxysporum f. sp. albedinis or the red weevil. The red weevil (R. ferrugineus) in particular causes severe damage to date palm estates in Saudi Arabia. Two methods are available for *in vitro* multiplication of date palm: shoot culture and somatic embryogenesis. For commercial micropropagation, shoot culture is the preferred method (42a) as the risk of genetic variation is considered less than with somatic embryogenesis.

The first report of clonal multiplication of date palm was made in 1979 by Poulain (42b). Over the last decade, micropropagation of date palm has played a key role in making more plants available to growers in the region. In most cases micropropagated plantlets have been imported from outside the region.

Twyford Plant Laboratories Ltd., a company based on the United Kingdom of Great Britain and Northern Ireland, managed to propagate 10,000 plantlets of date palm which were sold at a unit price of US$ 20, to Saudi Arabia, Oman and the Islamic Republic of Iran in 1986. The plantlets were obtained through somatic embryogenesis (4a). DNA markers have been developed to check that the genome of the plantlets is identical to that of the mother plant.

Within the ESCWA region, plant cell and tissue culture is the most well established biotechnology in terms of the number of private companies, universities and government research bodies involved (see table 2). Egypt has the most experience in plant cell and tissue culture and two major private companies have been active in mass-propagation and export of potato tubers since 1990. Other countries of the ESCWA region with more extensive experiences in plant cell and tissue culture techniques include Jordan, Saudi Arabia, and the Syrian Arab Republic.

TABLE 2. NUMBER OF INSTITUTES IN ESCWA MEMBER COUNTRIES ACTIVE IN PLANT CELL AND TISSUE CULTURE IN 1996

ESCWA member country	Number of companies	Number of universities	Other*
Egypt	2 (90,91)	6 (5e)	4 (5e,5f,66,74,90,91)
Jordan	3 (5g,40,92,93)	3 (5g)	1 (5g)
Syrian Arab Republic	1	2	1
Saudi Arabia	1 (98)	1 (100)	3 (98,99,103)

* Including public research institutes and foreign donor projects.

Note: Numbered references in this table correspond to references in the complete study on "Biotechnology in the ESCWA Member Countries: Sectoral Issues and Policies" of which the present paper is a summary.

A. EGYPT

Plant cell and tissue culture techniques have been successfully mastered in Egypt, covering the full range of plant tissue culture techniques (e.g. shoot organogenesis, somatic embryogenesis, *in vitro* pollination). Moreover, most Egyptian academic institutions have been involved in plant tissue culture over the past decade.

Since 1990 private initiatives in Egypt resulted in setting up two firms which are now established - Danton (Lebanese ownership) and Picco - and which routinely use basic tissue culture techniques for mass propagation of potato, banana, strawberry and ornamentals. Picco, in particular, has been very successful, with approximately US$ 2.5 million exports and 15,000 acres of land for fields, greenhouses and laboratory facilities (23,24). Picco has bought ELISA test kits from AGERI, located in Giza, to test potato mini-tubers for the presence of viruses (15,19). For establishing their technological know-how for virus-free production of potato mini-tubers, Picco consulted with the Plant Cell & Tissue Culture Department of the Egyptian National Research Center (NRC)(24).

B. JORDAN

Jordan's experiences and achievements in PCTC are mainly geared towards micropropagation and have been established over the past five to seven years. Commercial activities and most research activities are aimed at the production of virus-free potato mini-tubers. This technology is internationally well-established and the cost-benefits have proved to be positive. Initial investments are low and a short-term return on investments is guaranteed. According to international estimates, the use of virus-free potato seed can increase potato yields by 30% to 50%. The potato seed tuber market requirements for Jordan in 1993 were in the range of 9,500 tons with a market value of 3.2 million Jordanian dinars (33a). Of this, 7,100 tons of potato seed tubers were imported in 1993.

C. SAUDI ARABIA

Through the grant programme of KACST (King Abdulaziz City for Science and Technology), two basic research initiatives in plant tissue culture were sponsored for three years at King Saud University in

Riyadh. One project, conducted by the plant protection department of King Saud University, focused on the serological typing of potato virus diseases, using ELISA, and the subsequent development of a tissue culture protocol for producing virus-free potato mini-tubers. The total grant from KACST amounted to 883,375 Saudi Arabian riyals (SRls) (37a). The second project was still ongoing at the time of this writing and is concerned with induction and selection of salt- and drought-tolerant lines of wheat by plant tissue culture. The total grant amounts to SRls 625,000 (37b).

Most plant tissue culture activities in Saudi Arabia are geared to the date palm. Even some private commercial activities have materialized in recent years. Because propagation of date palm is difficult, tissue culture forms a good alternative to traditional offshoot propagation.

All public research institutes in Saudi Arabia working on date palm indicated they have insufficient funds for chemicals and equipment (36). There is little communication between the different research groups, and there is no coordination. Only the National Agricultural and Water Research Center of the Ministry of Agriculture has achieved mass-scale micropropagation of date palm. In 1990 the five-year plan (1990-1995) of Saudi Arabia put heavy emphasis on privatization (6a), opening the way for private initiatives in date palm tissue culture.

Current private initiatives in date palm micropropagation are limited to one company in Dammam. According to the general manager of the company, the Saudi American Plant Development (SAPAD), operations started in 1992 (38). SAPAD relies on micropropagation protocols of the Escagenetics corporation, an American public company. Both organogenesis and somatic embryogenesis protocols are used for commercial micropropagation. The company could not report the use of DNA probes or protein analysis for testing the similarity of the plantlets to the original mother plant material. Escagenetics conducted field trials with tissue culture propagated date palms in the United States and the Middle East for 12 years. Commercial sales of 10 superior date palm varieties started in September 1996. Price levels range between SRls 150 and SRls 500, depending on the variety and age of the plantlet (38).

The price levels of SAPAD for date palm plantlets can easily compete with current price levels of traditional offshoots. Nevertheless, price levels of three-years-old offshoots of date palm witnessed a considerable drop in prices over the past decade, from SRls 3,000 - SRls 6,000 in 1985 to SRls 500 - SRls 1,000 in 1996 (36). This is mainly due to increased production of offshoots and less demand from farmers.

In 1996, the Government of Saudi Arabia decided to destroy 850,000 trees infected by the red weevil. Although this mainly concerns old, non-productive trees, this will still increase the demand for date palm plantlets in the near future. Some wheat farmers are changing to date palm cultivation as wheat subsidies have been drastically reduced over the past few years. For some years, the Government of Saudi Arabia has restricted the import of date palm germ plasm because of fears of plant diseases. If companies such as SAPAD could increase their sale figures, this would result in reduced prices of date palm plantlets for tissue culture plantlets. In addition, this would make the technique a more promising alternative to traditional offshoot propagation.

The mass propagation of date palm is especially important for Saudi Arabia because it is a crop harnessing the water-holding capacity of arid soils. One of the genetic centres of origin of the date palm is in the eastern province of Saudi Arabia (Hofuf area). The multitude of different varieties of date palms is highly appreciated by Saudi Arabian consumers, and dates from superior varieties such as Nbootsafe, Rothana, Sukai, Sukhari, and Sultana fetch high prices.

D. Syrian Arab Republic

Like other ESCWA member countries, the core of the Syrian Arab Republic's activities in biotechnology is for crop improvement. Biotechnology research and applications are basically restricted to tissue culture techniques.

In 1987, a plant tissue culture laboratory was set up by GOSM and furnished with locally manufactured equipment. The laboratory facilitates both research and micropropagation of virus-free potato shoots for large-scale production of potato seeds (i.e. tubers). Research on the potato started in 1988, and mass-scale propagation of virus-free potato tubers first began in August 1995, when a new 1,000 square-metre greenhouse, costing US$ 600,000 and manufactured in the Netherlands, was set up. The organization has additional greenhouses (5,000 m^2) and 15,000 m^2 of net-houses near Tartous to further propagate the virus-free potato tubers (26).

By the end of 1995, GOSM was producing 3% of the total Syrian requirements for virus-free tubers and its goal was to cover the entire demand by the end of 1996. GOSM has an advantage in that it is currently the only distributor in the Syrian Arab Republic for seeds of potatoes, cotton, wheat, barley, sugarbeet, maize, groundnuts, chickpeas, soybeans, broad beans, lentils and peas. Moreover, GOSM has a yearly budget of US$ 90 million, providing sufficient financial resources for research as well as seed multiplication. In 1990, GOSM initiated research on establishing date palm micropropagation protocols. The Syrian market needs 100,000 date palm seedlings yearly. So far no breakthrough in establishing suitable protocols for mass-scale propagation of date palm has been reported (26).

Over the last few years, ICARDA started tissue culture activities. Plant cell and tissue culture activities are mainly geared to supporting breeding programmes enabling wide crosses, using embryo rescue (lentils) and ovule culture (chickpea). Research on producing doubled haploid of wheat and barley, using anther culture, started in 1988; it resulted in doubled haploid lines in bread wheat, of which 600 were tested in the field (12,28a).

The most recent and only private initiative in plant tissue culture concerns a small company employing approximately 100 employees. Work started in 1995 on the micropropagation of ornamentals (26).

III. STATUS OF BIOTECHNOLOGY POLICIES IN THE ESCWA REGION

Clearly, developments in biotechnology in ESCWA member countries are not homogeneous but differ from country to country. The major differences between the four countries under examination in this study are indicated in table 3.

TABLE 3. STATUS OF BIOTECHNOLOGY DEVELOPMENT IN FOUR SELECTED ESCWA MEMBER COUNTRIES

Biotechnology parameters	Egypt	Jordan	Saudi Arabia	Syrian Arab Republic
Biotechnology policies	+	++	+	-
Genetic engineering research of Plants	+++	+	+	+
PCTC research	++	++	+	++
Quality of human resources	+++	+++	++	+++
Access to international technology	+++	++	++	+
Commercial biotechnology services	++	+	+	+

Sources: ESCWA, Inter-Agency Task Force Meeting, Biotechnology Applications and Technology Transfer, Survey of Biotechnology Activities in Egypt, mission report on visit to Egypt, 16-21 December 1995, ESCWA secretariat, Amman; Mission report on visit to the Syrian Arab Republic, Survey of biotechnology activities, 3-7 March 1996, ESCWA secretariat, Amman; and ESCWA, mission report on date palm micropropagation in Saudi Arabia, 19-24 October 1996, ESCWA secretariat, Amman.

Notes: (-); means absent; (+) means initiated; (++) means established; (+++) means international competence.

A. EGYPT

Egypt's human resources in biotechnology are both abundant and highly trained. In 1992, more than 4,000 scientists were active in the field and many of them were trained in universities in developed countries (43a). This reflects directly on the quality of established research activities for genetic engineering and plant tissue culture. There are, however, large differences between research institutes concerning available resources. In addition, biotechnology research is not directly linked to other national agricultural research institutes. This is reflected by the status of policies in this area: policy formulation for biotechnologies has just been initiated.

B. JORDAN

Jordan is the only exception of the four countries surveyed in which specific biotechnology policies are being implemented. A grant system for stimulating national biotechnology research assured a competitive environment in which several plant tissue culture initiatives (both commercial and research) emerged. Plant molecular biology research has yet to be initiated.

The Higher Council for Science and Technology is responsible for the formulation of policies and strategies regarding biotechnologies in Jordan since 1992. The first National Science and Technology Policy was prepared in 1995: biotechnology was not included as a separate chapter but rather integrated into other priority areas. Emphasis was placed on biotechnologies with reference to water, land resources, environment and energy, as these constitute priority areas within the policy of the Council. Final policy decisions are taken by the Ministry of Agriculture and the Ministry of Planning.

C. SAUDI ARABIA

Egypt was about to implement its first biotechnology strategy at the time of this writing and Jordan has been doing so since 1992. Saudi Arabia still has to formulate policy priorities for biotechnology at the country level. However, in the period from 1972 to 1993 KACST allocated more than SRls 15 million to 14 specific biotechnology-related projects. This amounts to approximately 5% of the total project research budget of KACST. The lion's share (i.e. 65%) of KACST financial support for biotechnology research is in the area of health and medicine. Agrobiotechnologies receive 12% of total research funds spent on biotechnology.

In 1995 a special genetic engineering and biotechnology programme was initiated at KACST to determine research priorities and modalities for organizing biotechnology research. Some research, including molecular biology research, is planned at KACST itself. Other preliminary plans are focusing on the establishment of a centre for genetic engineering and biotechnology (47).

D. SYRIAN ARAB REPUBLIC

Of the four surveyed ESCWA member countries, the Syrian Arab Republic is the only country that does not have a coordinating body for biotechnology. As a consequence, no attempts to formulate biotechnology policies at the national level have been initiated (see table 3). This is characteristic of the way in which the Syrian Arab Republic has organized national authoritative coordinating responsibilities in agricultural research: no fewer than three ministries (Ministry of Agriculture and Agrarian Reform, Ministry of Economy and External Trade, and Ministry of Irrigation) are involved in the planning of public agricultural research (45a).

This segregation of responsibilities is not necessarily without benefits. Individual research authorities which are often established according to crop commodities (e.g. cotton bureau, citrus bureau) can adjust priorities rapidly, creating the necessary flexibility to respond to problems in agriculture or opportunities in research. One such authoritative research body in the Syrian Arab Republic recently decided to explore the opportunities offered by biotechnology: the Atomic Energy Commission of Syria (AEC). AEC is an integral unit of the Syrian Prime Ministry, and is given a certain degree of autonomy (46).

IV. RECOMMENDATIONS FOR ORGANIZING AGRICULTURAL BIOTECHNOLOGY RESEARCH

A. TECHNOLOGY TRANSFER AND DEVELOPMENT

The acquisition of sophisticated biotechnologies generally presupposes the existence of adequate technological capabilities in a range of areas. This makes it difficult for developing countries to gain a foothold in this area.

Therefore, developing countries should act with caution in focusing on the more advanced biotechnologies. In most non-industrialized countries there is a lack of self-confidence concerning domestic technological capabilities. Foreign capital goods are often superior in performance and durability, feeding the incorrect presumption that domestic human and non-human resources are not sufficiently equipped to solve local problems. In turn this results almost automatically in an over-reliance on importing an entire set of required technologies, rather than developing proprietary technologies based on the blending of local capacities with the more well-established foreign technologies. This should not restrain developing countries from attempting to develop more advanced technologies as a basis for improving local R&D capacities. The importance of more refined modalities for international technology transfer was elegantly highlighted by Jason Zunsheng Yin, who wrote that indigenous technological capability factors are determinants of the economic and technological success of the transfer projects, and that less developed countries should formulate a strategy for acquiring foreign technology to be consistent with their technological capability (41).

Examples of international biotechnology transfer, in particular in Egypt and Saudi Arabia, strengthen this observation. The most successful technology transfer project, on genetic engineering of plants, is being executed in Egypt. Since its establishment in 1989, the National Agricultural Genetic Engineering Laboratory/(NAGEL) achieved a breakthrough in genetic engineering of potatoes by regenerating three commercial potato cultivars with a chimeric gene encoding the coat protein of potato X virus. Genetic engineering technology was established through technical assistance from UNDP and USAID (United States Agency for International Development). However, the genetic engineering techniques of NAGEL have, so far, not been made available to seed-distributing agencies or farmers. The indigenous technological capability of Egypt in this area is not yet ready for commercial use of the related advanced technology.

Another example of the relevance of indigenous technological capability to ensure the success of biotechnology transfer projects is in the area of date palm micropropagation in Saudi Arabia. This particular biotechnology is especially promising, as traditional propagation through offshoots is expensive and time-consuming. In 1986, the Date Palm Research Centre of King Faisal University in Hofuf planted the first *in vitro* derived date palm, based on a somatic embryogenesis protocol. In the international literature on the subject, somatic embryogenesis is seen as less promising than shoot culture as the former may lead to genetic variation of the propagated clones, making it difficult to predict whether the performance of such plants will be comparable to that of the mother plant. In subsequent years, three research institutes gradually developed the capacity to experiment and develop tissue culture protocols for date palm. The Date Palm Research Centre in Hofuf first established a more appropriate shoot culture protocol in 1995, whereas the National Agricultural Water Research Centre in Riyadh has mastered the large-scale production and distribution of tissue culture propagated date palms to farmers since 1992 (21,500 plantlets in 1995 (39)). The latter institute, however, is relying on a somatic embryogenesis protocol, with the consequent disadvantages. The first effective commercial technology transfer of date palm micropropagation was in September 1996, when a private Saudi Arabian company in Dammam (SAPAD) started selling plantlets of 10 date palm varieties propagated by both somatic embryogenesis and shoot culture. The SAPAD proprietary micropropagation process was developed by ESCAGENETICS Corporation, an American public company.

These examples indicate that it will take considerable time and effort to establish indigenous biotechnology capacity in ESCWA member countries. In addition, advanced agricultural biotechnologies are less likely options for short-term technology transfer than well-established biotechnologies, such as the production of virus-free potato tubers by tissue culture.

There is not much reason to embark on the genetic engineering of plants if the local technological capability (e.g. mastering of plant regeneration protocols, basic molecular biology techniques) is not sufficiently developed. It is not feasible to try to skip several phases of the technology development process by importing the entire set of required techniques as one complete technology package. Considerable time and planned efforts are required to first develop the more generic techniques which could culminate in the development of more advanced technologies such as genetic engineering. Only in those cases for which considerable financial resources can be allocated for 20 or more years will it pay to invest directly in genetic engineering research of plants.

Four ESCWA member countries have somewhat more experience in biotechnology. These countries are Egypt, Jordan, Saudi Arabia and the Syrian Arab Republic. A more detailed account of suggested policy recommendations will be presented below.

B. EGYPT

At present the Egyptian Government has not set any priorities for which sectors are to benefit from biotechnology. The Academy for Scientific Research and Technology in Egypt suggests that efforts focus on agriculture. A consultant from the United Nations Industrial Development Organization (UNIDO) noted that there was a very wide perceived gap between the results of current international research in agriculture and the reality in Egypt and therefore research on agriculture was of top priority (16c).

Based on the findings of the study summarized by this paper, it is felt that agricultural research in biotechnology receives far more support than other sectors such as industrial fermentation and medicine. The latter two sectors promise a more direct return on investments in advanced biotechnologies. The in-house development and production of enzymes using bioreactor technology could directly feed into more commercial gains in the detergent and food industries and for production of clinical diagnostic enzyme kits. Investments for expanding molecular biology techniques for cancer-diagnosis in medicine would directly decrease the total health bill of a country. Egypt should award more priority to those sectors in evaluating biotechnology.

The following observations may be made as a result of the preliminary ESCWA survey of biotechnology activities in which Egypt is relatively more advanced. There is, primarily, a need to formulate a clear strategy for biotechnology research. Despite the high quality of available human resources, the research infrastructure and funding patterns remain seriously in need of coordination. Greater benefits can be obtained if research institutes reorganize and adopt market-oriented policies and organizational structures to stimulate income generation for operation and expansion. Existing institutions should also consider establishing networks and other arrangements to ensure an effective division of labour among themselves. This should create a more competitive scientific environment which would enhance research potential in general. External assistance may then be used to provide support to research groups on a more even basis over a longer time span. Finally, institutions active in biotechnology research should implement modes of planning and operation that directly link their research with commercial initiatives.

C. JORDAN

The emergence of a science and technology policy as formulated by the Higher Council for Science and Technology, and suited to the direction of the 1993-1997 Jordanian Development Plan, implied a major positive change as opposed to previous development plans. This stimulated the emergence of several public and private initiatives in micropropagation. To assist further development, more detailed policies and support mechanisms are needed, especially for the production of potato seed-tubers.

Jordan's potato productivity in terms of yield per hectare is the highest among the ESCWA member countries, and reached 24 tons/ per hectare in 1993. The limited area for cultivation and the comparatively high yield limit the potential for increasing productivity and thus limit the potential contribution of virus-free potato seed tubers to increasing potato production in Jordan. There is, however, an incentive for private Jordanian companies to explore the production of high quality potato seed tubers as 75 % of Jordan's requirements are currently imported (22). The investment margin available for producing virus-free potatoes allows four to five small companies to operate on the Jordanian market; if market access could be obtained to other countries in the region, the number of such companies could increase. An added benefit for exploring the production of virus-free potatoes in Jordan may well be a lower unit price of seed tubers, which would benefit farmers. Jordan could also save foreign currency of up to US$ 3.4 million if imports could be replaced by local production of seed tubers (33a).

It is obvious that the development and commercialization of biotechnologies is in its infancy in Jordan. Research in biotechnologies will need more long-term investments to boost capacity and, thereby, the confidence of investors. This is clearly a vicious circle; without investments the research bodies will not build more capacity to obtain more investments. The intermediatory role of the Government of Jordan is required to bring together both sides (research bodies and investors) and to provide incentives for investments in biotechnologies, as well as supply legislative (e.g. customs) support to improve the prospects of return on investments.

Based on the above, the following suggestions are made for formulating policies to increase the efficiency of biotechnology transfer and development in Jordan.

Jordan would benefit from more national coordination on biotechnology to achieve the following goals:

(a) Unite the interests of public research and private companies;

(b) Involve all interested parties for the identification of national demand issues and the interests of biotechnology suppliers and beneficiaries;

(c) Avoid duplication of public research efforts (as is the case with the production of virus-free potato seed tubers);

(d) Ensure a national regulatory framework for the import and export of biotechnology-related raw materials and products;

(e) Reduce Government legislation that negatively influences biotechnology transfer and development.

Since biotechnologies have only been recently established in Jordan, the country would benefit from more flexibility in public research spending, allowing for different mechanisms and levels of Government

support and involvement in R&D activities, depending on the prospective economic benefits of biotechnologies. Measures to link technology demand with R&D in biotechnology include the following, listed below.

(a) In generic biotechnologies (e.g. micropropagation of selected crops) with low investment risk characteristics, private companies should be allowed to absorb fully research groups with continued financial Government support. Government support could continue until the research department has been absorbed in the production line of the private company, or has become self-reliant in terms of financial revenues.

(b) An alternative to point (a) would be for the Government to allocate a special research budget for sponsoring R&D activities in generic biotechnologies up to a previously agreed amount. A precondition could be that interested organizations (e.g. research bodies, private companies) should all collaborate and that the technology should be vital to the organizations.

(c) Special Government grants could be awarded to research initiatives that are both innovative and related to products for the export market; the Higher Council for Science and Technology already harbours a special research grant fund for innovative research and may thus include extra conditions related to the relevancy of biotechnologies for the export market.

(d) For medical biotechnologies, the pharmaceutical industry and hospitals could be united to establish a joint medical research fund.

(e) For agricultural biotechnologies, target groups (i.e. agricultural producers) could unite to establish private research funds.

To allow for the involvement of all relevant actors in the process of national coordination of biotechnology transfer and development activities, biotechnology focal points should be established with interested public and private sectors. In Jordan the following sectors have an interest in biotechnologies:

(a) Private agricultural supply and marketing companies;

(b) The private pharmaceutical sector. In March 1997 a seminar on biotechnologies for pharmaceutical manufacturers was organized in Jordan by the Arab Union of the Manufacturers of Pharmaceutical and Medical Appliances (AUPAM). Jordanian private pharmaceutical companies financed part of the seminar.

(c) The agricultural research sector represented by the National Centre for Agricultural Research and Technology Transfer.

(d) The food-production industry.

Encouragement of promising researchers could be achieved through incubator projects. The human resources of Jordan in science and technology are noteworthy in the ESCWA region. Scientists who have promising biotechnology research agendas may be supplied with added incentives in the form of research grants and business and commercial training.

D. Saudi Arabia

In evaluating the prospects for biotechnology to support potato and date palm production in Saudi Arabia, it is clear that there is a need for central registration and coordination of research efforts, technology

development and commercialization. Such central coordination may ultimately target sustainable large-scale commercial production and marketing of micropropagated date palms and potato mini-tubers. The most favourable scenario may even include Saudi Arabian institutions exporting such seedling material.

Much is needed before such favourable developments could take place. Although no specific biotechnology policies are needed, it may be a good idea to develop specific date palm and potato seedling multiplication policies. Such policies dealing with biotechnology should include all of the following elements:

(i) Core technologies (e.g. micropropagation protocols, quality control) to be developed and mastered by Saudi Arabian institutions;

(ii) Core technologies to be assembled into a production line;

(iii) Retail, distribution and marketing channels for micropropagated seedling material to be established;

(iv) Information and extension services (e.g. demonstrations, follow-up, quality tests) to guarantee optimal use and application of micropropagated seedling material.

In the case of potato micropropagation, core technologies, including a standard protocol for a growth medium and quality tests which can monitor whether the propagated material is virus-free, have already been developed at King Saud University. For date palm micropropagation, quality tests which can confirm the superiority of seedlings still have to be developed. In both cases, the main challenge remains the successive follow-up indicated in items (ii) to (iv) above.

In most developing countries—and in this case also in Saudi Arabia—no industry has been fully developed for the micropropagation of date palm or potato. In other words, for such countries, public-private collaboration is a prerequisite in order to ensure the provision of new commodities to the public in the country concerned.

The active involvement of private investors and companies has the added advantage that this sector is much better equipped to secure retail, distribution and marketing channels for date palm and potato seedlings, especially when it is planned to explore the possibilities of exporting germ plasm.

The above policy recommendations emphasize an increasing role for the private sector and a diminishing role for Government authorities. The opposite is true. Only by setting clear priorities and translating them into central registration and coordination will the newly emerging Saudi Arabian private community be able to respond effectively to new opportunities in this field.

Concerned Government authorities have an even more important role, which is to protect the quality of both the process and the end-product. Investors in non-industrialized countries, Saudi Arabia not excluded, have to focus on short gestation periods because of the volatility of the market. Therefore, newly established private companies will probably try to cut costs concerned with services to costumers and quality control of the end-product. In both date palm and potato micropropagation, quality control is not only an essential element of the product but is also based on advanced biotechnologies (e.g. ELISA for potato, and DNA (deoxyribonucleic acid) finger-printing or amino-acid/protein analysis for date palm). The development of technologies for quality control and the setting of quality standards are exclusively Government tasks in the initial phases of establishing a micropropagation industry. Once private companies are well established, the

sector will automatically recognize that sales can only be sustained by keeping the clients happy. In due course, companies will therefore increase their investments in quality control and general services to clients.

E. Syrian Arab Republic

In contrast to the other countries surveyed, no biotechnology policies or coordination activities were reported in the Syrian Arab Republic. Policy formulation and implementation is needed to guide the expansion of micropropagation techniques to other crop commodities. Policies could try to involve private companies, as noted above for Jordan and Saudi Arabia. In the case of the Syrian Arab Republic, more overt coordination between crop research institutions and the three ministries involved in planning public agricultural research (Ministry of Agriculture and Agrarian Reform, Ministry of Economy and External Trade and Ministry of Irrigation) is needed.

At present the Atomic Energy Commission of Syria may well be the most suitable agency to coordinate R&D as well as technology transfer into relevant sectors where biotechnology is expected to play a leading role. As a multidisciplinary agency, the Commission is already executing and planning biotechnology research in different areas related to agriculture and health. Its multisectoral experience may be employed to implement policies aimed at coordinating promising initiatives in biotechnology transfer.

PART TWO

BIOTECHNOLOGIES FOR INDUSTRY AND HUMAN HEALTH

V. BIOTECHNOLOGY IN INDUSTRY

Without exception, all ESCWA member countries have developed conventional (i.e. no use of genetically engineered organisms or molecules) fermentation technologies. Complete biotechnology products which are manufactured in the region include cheese, ethyl alcohol, yoghurt and baker's yeast.

Most countries in the region have established modest industries for the production of fruit and vegetable juices, utilizing enzymes for thickening, removal of bitter taste or to dissolve turbidity. Other product groups for which biotechnologies are used in part for the manufacturing process include the canning industry as an example of sterilization bioreactor technology. Other sectors which are well established in the region, and for which biotechnologies are used as supportive tools, are the leather industry (i.e. enzymes for tanning of skins and hides), the alcoholic beverages industry (i.e. fermentation), and the detergents industry (i.e. proteolytic enzymes).

According to a 1993 United Nations study (32a), modern wastewater reuse facilities are currently functioning in seven countries of the region. These are Bahrain, Jordan, Kuwait, Oman, Qatar, Saudi Arabia and the United Arab Emirates. In all cases, secondary treatment of wastewater was reported using aerobic digestion such as the activated sludge-system, followed in some cases by rapid sand filtration.

In general, the existing wastewater treatment plants and wastewater collection system coverage and performance in the region are inadequate (32c). Quality guidelines on the effluent of wastewater treatment plants often disregard the end-use of treated wastewater: irrigation for agricultural purposes. The removal of pathogenic organisms, such as helminths, protozoa and bacteria, is crucial to avoid increased infection rates among rural populations.

Pollution levels in domestic wastewaters in the arid areas of Western Asia are more concentrated than those in Europe and the United States, by up to five times. This has serious consequences for the occurrence of water-borne diseases such as ascariasis (roundworm), trichuriasis, hookworm and schistosomiasis. The incidence of infections is further aggravated by the use of effluent for irrigation purposes. In addition, the commonly used activated sludge-system is not efficient in removing pathogenic organisms.

EGYPT

Bioreactor technology in Egypt is utilized within many different sectors, ranging from biological nitrogen fixation applications in agriculture to the production of organic solvents and vaccines. Bioreactor technology has a long history in Egypt, as the first inoculum production of nitrogen fixing bacteria was achieved in 1939 at the Agricultural Research Center (3f). Bioreactor technology used for inoculum production of nitrogen fixing bacteria is a completely mastered technology, as five out of the seven major research institutes working on bioreactor technology in Egypt are active in this field.

Commercial activities, however, have not been reported in this field. For large-scale applications of bioreactor technology in industrial production (food, organic solvents, detergents, disease diagnosis kits) Egypt has to rely on the import of enzymes (mainly peroxidase and urease), and the tools to carry out the digestion process (20b).

Concerning waste treatment, as of 1950, Egypt started to develop the capacity to produce methane (biogas) through the fermentation of rice straw. In 1986, around 50% of the available rice straw in Egypt (over 1 million tons) was utilized for composting and, to a modest extent, for methane production in small-scale, rural-based plants (3k).

Conclusions

1. Biofertilizers and wastewater treatment plants will have to rely more heavily on government promotion of their applications. In both cases, investments are not likely to yield direct returns. In the case of biofertilizers, a market demand is not present and farmers will have to be educated to understand the potential benefits. Only farmers who can afford and practice good crop stands are likely to benefit from biofertilizers. Farmers are, therefore, likely to lose interest rapidly in this market unless Governments provide additional incentives. Governments may be interested in biofertilizers since the use of properly inoculated leguminous crops can restore soil fertility over the long term.

2. In the ESCWA region, the benefits of sound biotechnology-based wastewater treatment methods are obvious. The reuse of treated sewage for irrigation purposes can counter the increasing depletion of non-renewable water resources in the region. It is, however, not the availability of the technology that is the crucial factor for success. The formulation of agreements and coordination of collaboration between the partners in the technology transfer chain (e.g. municipalities - public research - sewage treatment plant - farmers) are needed to specify the available resources and needs for the technology. This will ensure the best choice of a wastewater treatment system from the many model systems. Since most systems are well-researched, the technology is generic in nature and thus easily accessible.

3. It is clear that the most direct commercial opportunities for exploring enzyme and bioreactor technology are in the more conventional application areas, such as food (including beverages), detergents and leather-manufacturing industries. These industries are well established in most of the ESCWA member countries. Local markets are sufficient to warrant investment and investors can expect short time frames for returns on investments.

VI. BIOTECHNOLOGIES IN HUMAN HEALTH CARE

Since the advent of the first transgenic product (e.g. insulin) for human use in 1982 (31a), medical biotechnologies have received increased attention from the public and the private sector. For this reason, most commercial opportunities in biotechnology are in human health.

Together, therapeutic and diagnostic biotechnology products accounted for almost 70% of total sales in the United States in 1994. This almost exclusive interest of the American private sector in medical biotechnologies has been prevalent for more than a decade. Similar trends are also dominating in other industrialized countries. In Japan, out of 268 companies, 67% were involved in pursuing biotechnology research and development in pharmaceuticals and diagnostics, in 1987. In Western Europe, 42% of companies were active in human health in 1994 (40a).

A. EGYPT

In Egypt, biotechnology applications in the field of health and medicine consist of the commercial production of vaccines and antibiotics using bioreactor technology. More advanced research is concerned with developing diagnostics such as DNA and RNA (ribonucleic acid) test kits for the detection of viral diseases, cervical cancer and chronic myeloid leukaemia.

B. JORDAN

In Jordan, research and development in enzyme and bioreactor technology are mainly being carried out in the veterinary industry.

The best established company using bioreactor technology in Jordan is the Jordan Center for Veterinary Vaccines (JCVV). JCVV was established by the Government of Jordan and the German technical cooperation organization GTZ (Gesellschaft für Technische Zusammenarbeit) in May 1988. JCVV is capable of mass production of various viral and bacterial vaccines for veterinary purposes. The quality of production is reported to be of international standard. The facilities are also suitable for the production of human vaccines. At present the total production capacity is underutilized as only 1% of the total output capacity is utilized. The total production capacity could cover a major part of the total regional demand for veterinary vaccines. Through intense negotiation efforts by GTZ, JCVV was privatized at the end of 1996. The vaccine production plant adheres to ISO 9000 standards, which should improve access to export markets (34).

C. SYRIAN ARAB REPUBLIC

Reports on the considerable size of the pharmaceutical industry in the Syrian Arab Republic, in which a total of 44 private companies and 2 public companies are active with total market sales of approximately US$ 120 million (35), indicates the potential of biotechnological product groups including hormones, antibodies and vaccines. However, no reports have been issued on using biotechnology in the production of pharmaceuticals, except for the subject of microbial contamination control. One plant in Aleppo produces intravenous vaccines, another plant in Damascus plans to produce hormones, and most plants surveyed report the production of antibiotics. The raw materials of these product groups, for which biotechnology is a prerequisite are all imported.

In the field of veterinary vaccines, a small plant was set up as a joint project between GTZ and the Ministry of Agriculture. Production covers 70% to 80% of the total Syrian market (35).

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