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BIOTECHNOLOGY AND SUSTAINABLE CROP PRODUCTION IN ZIMBABWE

by

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RÉSUMÉ

Cette étude de cas examine les progrès des biotechnologies au Zimbabwe, pays dans lequel la recherche agronomique, la sélection végétale et la production de semences améliorées sont bien développées. Les obstacles à la recherche en biotechnologie, au progrès technique et à sa diffusion sont évalués, notamment du point de vue des ressources disponibles et des mécanismes de transfert technologique vers les diverses catégories d'agriculteurs.

Dans le cas des grandes exploitations agricoles du Zimbabwe qui commercialisent leur production, les applications des biotechnologies seront adoptées principalement si leur avantage comparatif économique est supérieur à celui des techniques actuellement utilisées. En revanche, il est peu probable que les innovations des biotechnologies (notamment sous forme de semences) soient adoptées par les petits paysans et les exploitants de terres communautaires, si des mesures spécifiques ne sont pas prises pour résoudre les problèmes d'approvisionnement en semences.

SUMMARY

This case study of Zimbabwe has examined developments in biotechnology against the background of a well-developed national agricultural research, plant breeding and seeds system. It has then assessed the constraints to biotechnology research, technology development and diffusion in the light of the resources available and the technology transfer mechanisms in place for different groups of farmers.

The study concludes that, in the case of Zimbabwe's large-scale commercial farmers, the transfer of biotechnology applications will be determined essentially by their economic advantage over techniques currently in use. In the case of the small-scale and communal areas farmers, it is unlikely that biotechnology innovations — particularly when delivered as seed — would be adopted unless special policy measures to address the problems of seeds supply, are taken.

PREFACE

This paper is part of a research project entitled *Biotechnology and Sustainable Agriculture,* undertaken in the context of the Development Centre's 1993-1995 research programme on *Sustainable Development: Environment, Resource Use, Technology and Trade***.** This project analyses developments in agricultural biotechnology, development and diffusion in order to determine whether biotechnology is likely to contribute to a more sustainable model of agricultural production in developing countries. This alternative model would be less dependent on the use of agro-chemicals and based more on biological pest and disease control and local genetic resources.

The research comprises a number of different components. These include a conceptual study of agricultural biotechnology in the context of a national innovation system and an analysis of publicly-funded international initiatives to stimulate the introduction of biotechnology in developing country agriculture. In addition, six country studies have been conducted: India and Thailand in Asia; Colombia and Mexico in Latin America; and Kenya and Zimbabwe in Africa. Country studies, which have identified both successes and failures in biotechnology initiatives, have sought to determine incentives and constraints in the successive phases of research, technology development and diffusion of biotechnologies for plant protection and production.

This study of Zimbabwe points to a well-developed agriculture sector, but at the same time highlights the dualistic nature of agricultural production, with large-scale commercial farmers using high levels of purchased technological and chemical inputs, and the small-scale and communal farmers using very few purchased inputs. The study also describes a well-developed national agricultural research and technology delivery system, but stresses that under structural adjustment financial resources for research are declining, while the public extension system is also under stress. This situation leads to two key policy implications.

Firstly, given the limited financial resources, it will be important to ensure interaction and balance between the newly-created Biotechnology Institute of the Scientific and Industrial Research Centre and the Department of Research and Specialist Services. The contribution of the latter in advances in conventional research and agricultural technology is essential in providing a solid foundation for the application of biotechnology innovations.

Secondly, while the large-scale commercial farmers are likely to adopt biotechnology innovations which provide an economic advantage over technologies currently in use, consideration will need to be given to specific policy measures to enhance the adoption of biotechnology innovations by the small-scale and communal farmers.

Jean Bonvin
President
OECD, Development Centre
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LIST OF ABBREVIATIONS

ABSP	Agricultural Biotechnology for Sustainable Productivity
ACIA	Agricultural Chemical Industries Association of Zimbabwe
AGRITEX	Agricultural Technical Extension Services
ARC	Agricultural Research Council
ART	Agricultural Research Trust
BFZ	Biotechnology Forum of Zimbabwe
Bt	Bacillus thuringiensis
CAF	Communal Area Farmer
CAMBIA	Centre for Application of Molecular Biology in Agriculture
CFU	Commercial Farmers Union
CIAT	International Centre for Tropical Agriculture
CIMMYT	International Centre for Maize and Wheat Improvement
CIP	International Potato Centre
CMB	Cotton Marketing Board
COPA	Commercial Oilseeds Producers' Association
CRI	Cotton Research Institute
DGIS	Directorate General for International Co-operation
DR&SS	Department of Research and Specialist Services
ENDA	Environment and Development Activities
FAO	Food and Agriculture Organisation
GMB	Grain Marketing Board
HRC	Horticultural Research Centre
IARC	International Agricultural Research Centre
ICRISAT	International Centre for Research in the Semi-Arid Tropics
IITA	International Institute for Tropical Agriculture
IPR	Intellectual Property Rights
IPGRC	International Plant Genetic Resources Centre
LIF	Legume Inoculant Factory
LSCF	Large Scale Commercial Farmer
NARS	National Agricultural Research System
NGBZ	National Genebank of Zimbabwe
RAF	Resettlement Area Farmer
RCZ	Research Council of Zimbabwe
SACCAR	Southern Africa Centre for Co-operation in Agricultural and Natural Resources Research and Training

SADC	Southern Africa Development Community
SAREC	Swedish Agency for Co-operation in Research
SIRDC	Scientific and Industrial Research and Development Centre
SPGRC	SADC Plant Genetic Resources Centre
SPRL	Soil Productivity Research Laboratory
SSCF	Small Scale Commercial Farmer
SSF	Small Scale Farmer
TRB	Tobacco Research Board
UZ	University of Zimbabwe
ZFU	Zimbabwe Farmers Union

INTRODUCTION

Background to the Study

The study was carried out in the context of the OECD Development Centre’s research programme on "Biotechnology and Sustainable Agriculture". The programme entails a number of country studies which are primarily intended to link initiatives in biotechnology to environmental concerns, reduction in the use of agro-chemicals and sustainable agriculture.

Objectives of the Study

The objectives of the study were to:

1. Review the macro-economic, agricultural and environmental background against which developments in biotechnology are occurring.

2. Provide an overview of the agricultural sector particularly with regard to its importance and structure, including farming groups and their production systems, agro-ecological zoning of the country and crop production.

3. Review crop research in the public, parastatal and private sectors as well the system for seed production and distribution.

4. Examine issues pertaining to pesticide use particularly as regards control, availability, incentives for reduced usage and environmental monitoring.

5. Examine national biotechnology policies and strategies, particularly as they relate to methods of plant production and protection.

6. Examine programmes and priorities in biotechnology research and the practices and policies in place to facilitate biotechnology research, product development and technology diffusion.

7. Assess the prospects for the development and diffusion of environmentally-sound biotechnology innovations in plant protection and production.

8. Assess the kinds of institutional arrangements and policies which will enable biotechnology to contribute to more sustainable approaches to crop protection and production.

Primary sources of information were particularly valuable in the compilation of information on pesticide use in the country. Thereafter, an analysis of the important issues pertaining to the study was undertaken primarily on the basis of the author's experience in, and knowledge of the agricultural sector in Zimbabwe. Where deemed necessary, the opinions of primary sources of information were also sought.

Organisation of the Paper

The paper is divided into six chapters. An introductory country and macroeconomic background is presented in the first Chapter.

Chapter 2 presents an overview of agriculture in Zimbabwe and includes discussions on the role and importance of the agricultural sector, farming groups and systems, and the production of various crops. A discussion on pesticides, particularly as regards legislation and control, use, availability and incentives for reduced usage is also included.

In Chapter 3 crop research undertaken by the public, parastatal and private sectors as well as international agricultural research centres is reviewed in some detail. Issues pertaining to plant breeding, variety release, seed production and distribution, genetic resources and policies are discussed in detail in view of their bearing on biotechnology. The chapter closes with a discussion on technology transfer and diffusion.

An overview of biotechnology in Zimbabwe is provided in Chapter 4. It includes discussions on national policies, strategies and priorities as well as a description of ongoing research programmes. The situation with regard to biosafety and intellectual property rights is also addressed in this Chapter.

In Chapter 5 a detailed analysis of opportunities for biotechnology intervention in crop production is presented including an analysis of the incentives for such intervention. The constraints to biotechnology research, technology development and diffusion are also discussed in detail followed by a brief discussion on the comparative cost-effectiveness of biotechnology intervention relative to conventional techniques. In the final Chapter, some general conclusions and policy implications are drawn.

I. COUNTRY AND MACROECONOMIC BACKGROUND

Zimbabwe is a landlocked country located in southern Africa between the Equator and the Tropic of Capricorn. It has a total area of approximately 390 245 square kilometres and extends from latitudes $15^{o}37'$ to $22^{o}24'$ south, and longitudes $25^{o}14'$ to $33^{o}04'$ east. The country is bordered by Zambia in the north and northwest, South Africa in the south, Mozambique in the east and northeast, and Botswana in the southwest. Its northern and southern borders with Zambia and South Africa are well defined by the Zambezi and Limpopo rivers, respectively.

The population of Zimbabwe is presently approximately 11 million and growing at a rate of about 3 per cent per annum. Over 70 per cent of the population resides in the rural areas and is largely dependent on agriculture. Zimbabwe is classified by the World Bank as a middle-income developing country with a per capita GDP in 1994 of less than US$650. The agricultural and mining sectors are its principal net producers of tradable commodities and, along with tourism, the country's primary net earners of foreign exchange. The major contributors to GDP in 1993 were manufacturing at 30.1 per cent, agriculture and forestry at 15.4 per cent and distribution, hotels and restaurants at 11.3 per cent. Transport and communications, and mining and quarrying contributed 7.3per cent and 5.5. per cent, respectively.

Soon after independence in 1980, the Government of Zimbabwe embarked on its policy of Growth with Equity which was largely founded on socialist principles. As a result, economic and fiscal policy up until 1990 was characterised by intensified state control, regulation of imports, exports, foreign exchange utilisation and employment of labour, and price determination of goods and services. Although government made considerable social progress particularly in education, health, population and small holder agriculture, this success was not matched by economic growth and rising per capita income.

In view of the declining economic performance experienced during the period 1980-1990, the Government of Zimbabwe launched its Framework for Economic Reform (1991-95) in 1991. In this Framework, Government enunciated an Economic Structural Adjustment Programme which is founded upon progressive economic liberalisation, deregulation and the removal of state controls, while seeking to motivate new investment, contain inflation and stimulate employment. The reform programme addresses the key policy constraints that hampered Zimbabwe's development in the 1980s, seeking an appropriate blend of structural reforms and macro-economic stabilisation measures. In particular, it calls for liberalising trade policy, restraining monetary growth, reducing the fiscal deficit to a sustainable level, and easing domestic regulation. The fundamental objective of the reform programme is to improve living conditions, especially for the poorest groups.

The economic reform programme produced mixed results and conflicting opinions. Positive effects include increased availability of both consumer goods and raw materials, increased competition due to deregulated price controls, more flexible labour relations, increased productivity, some improved business optimism and relaxation of bureaucratic controls related to foreign investment. Negative impacts include rapid devaluation of the Zimbabwean dollar with a resultant inflationary effect on imports, as well as escalating inflation and interest rates.

II. AGRICULTURE IN ZIMBABWE

Introduction

Although Zimbabwe possesses one of the most highly developed industrial sectors in Africa, agriculture is by far the most important economic activity in the country. About 80 per cent of the population is in some way dependent on agriculture for a livelihood. On average, this sector contributes about 14 per cent to GDP, 40 per cent of total export earnings, 50 per cent of raw materials for the manufacturing sector and accounts for approximately 30 per cent of formal employment. Despite the small share of agriculture in GDP, the Zimbabwean economy is heavily dependent on this sector for employment and exports, with the result that macroeconomic performance is closely linked to rainfall patterns. The sector is intimately interlinked with manufacturing as both a major user and supplier of products.

About 40 per cent of Zimbabwe's land area is classified as arable and 55 per cent as suitable for grazing. The total agricultural land is about 33 million hectares with approximately 18.9 per cent situated in the more advantaged agro-ecological regions and 59.8 per cent in the more marginal regions which are characterised by low and unreliable rainfall. Only about 37 per cent of the country receives more than 700 mm of rainfall which is required for semi-intensive farming and more than 75 per cent of the country is subject to conditions which make dryland farming risky.

A wide range of agricultural activities are undertaken by both small and large-scale farmers in the country. These include the production of a vast array of crops under rainfed conditions and the cultivation of selected crops under winter irrigation. Considerable livestock farming is also carried out under both intensive and extensive production systems. All agricultural activities are heavily reliant on rainfall and therefore subject to periodic failures due to drought.

Farming Groups and Systems

The Zimbabwean agricultural sector is often portrayed as bimodal or dualistic because the dominant farming groups consist of LSCFs and SSFs. Although this broad classification is generally correct, three agricultural subsectors can be identified. These include the economically dominant LSCFs, SSCFs and the numerically dominant CAFs.

The LSCFs are the economically dominant and most dynamic subsector which consists of approximately 4 500 farms averaging 2 500 hectares each. These farmers are generally well organised and financed and hence produce most of the marketable surplus. Most LSCFs are located in the better farming regions where they produce a variety of crops and livestock. Their production systems range from intensive high-cost horticultural operations to extensive livestock and game farming operations.

The SSCF subsector consists of about 10 000 farms of approximately 124 hectares each and occupies about 4 per cent of the total land area. The subsector is based on what were previously known as African Purchase Areas which were designated for purchase by African farmers only prior to independence in 1980. SSCFs thus have title deeds to their land and their farming methods are more akin to those of LSCFs, but less organised and intensive. However, this subsector has performed well below expectations.

SSFs or CAFs are numerically dominant and reside in the communal areas which consist of about 170 areas widely scattered over the country. They consist of about 1.4 million households and occupy approximately 16.4 million hectares or 42 per cent of the land area. Individual farming units are approximately 2.5 hectares and are supplemented by communal grazing for livestock production. Most CAFs and SSFs are engaged in both crop and livestock production. Their farming land is allocated by tribal chiefs and hence they have no title deeds. About 91 per cent of the communal areas are located in the poorer agro-ecological regions of the country. As a result, CAFs are the most disadvantaged subsector and are generally subject to a multitude of constraints. However, since independence government has attempted to improve conditions in the communal areas and provide improved support services to these farmers. The most obvious impact of this effort is evident in the phenomenal increase in maize and cotton production from this subsector. Despite the considerable efforts made by government, many SSFs continue to be seriously disadvantaged and marginalised.

Crop Production

A wide range of crops are produced in Zimbabwe under rainfed and irrigated conditions. The major crops include maize, cotton, tobacco, wheat, soyabeans and sugarcane. Deliveries of these crops, except sugarcane, to marketing agencies during 1980-1994 are shown in Table 1. Other important crops are coffee, groundnuts, sunflower, tea, sorghum, pearl millet, citrus and a number of horticultural crops which are assuming increasing importance as earners of foreign exchange. Minor crops include cowpea, barley, bambara nut, castor, beans, finger millet, potatoes, sweet potato and Michigan pea bean. A wide range of vegetables including tomato, cabbage, rape, okra, onions, cucumber, pumpkins, squashes, watermelon and leafy vegetables are also produced.

Maize

Maize is by far the most important food crop given that it is the staple for the vast majority of the population. Zimbabwe is generally considered to be an important maize producer in southern Africa and is a regular exporter to surrounding countries. The crop is produced by both LSCFs and SSFs primarily under rainfed conditions. While production by LSCFs is for sale and cattle feed, production by SSFs is mainly for home consumption with the surplus being marketed through both formal and informal channels.

The pattern of maize production by LSCFs and CAFs has altered considerably since 1980 with CAFs accounting for an increasingly larger market share. In 1980 CAFs accounted for only 10.6 per cent of maize deliveries to the Grain Marketing Board whereas in 1989 they accounted for over 63 per cent of the marketed crop. The reasons for this change include declining LSCF interest in the crop, mainly due to the low prices which prevailed until 1993, and a marked improvement in support services for SSFs after independence in 1980. The expected crop for 1993/94 is about 2.1 million tonnes of which about 1.5 million tonnes will be produced by SSFs.

Tobacco

Zimbabwe is the world's fourth largest producer of tobacco and has established an international reputation as a source of high quality flue-cured tobacco. Tobacco is the most important cash crop produced in the country and a major earner of foreign exchange. As such, the performance of the tobacco industry has a profound effect on the economy of the country.

In 1991 tobacco contributed 25 per cent to the country's export earnings with the contribution rising to 35.2 per cent in 1993. Production of the main flue-cured type has exceeded 230 000 tonnes and is estimated at 170 000 tonnes for 1993/94. The expected value of the 1993/94 crop exceeds Z$ 2.3 billion. In addition, production and processing of the crop provides about 80 000 jobs or 12 per cent of formal employment.

Cotton

Zimbabwe is the largest cotton producing country in sub-Saharan Africa and is renowned for its high quality hand-picked cotton lint. Cotton is the second most important cash crop after tobacco and a major foreign exchanger earner. In 1989 the crop was valued at over Z$234 million.

The crop is produced by LSCFs, SSCFs, and CAFs. In areas which are suitable for its production, it represents a major source of income for CAFs. Production in 1980/81 was 199 715 tonnes rising to a record crop of 323 268 tonnes in 1987/88. It is estimated that about 180 000 tonnes will be produced in 1993/94.

Cotton production has experienced explosive growth in area and output following a concerted effort by Government and the Cotton Marketing Board (CMB) to improve production in the communal areas after independence. In the period 1980-1991 area expanded at an average annual rate of 25 per cent, production at 26.5 per cent and yields at 1.3 per cent. The massive increase in output from SSFs is evident in the increase in their percentage contribution to the national crop. In 1980 they contributed only 11.4 per cent to total production whereas in 1990 their output constituted 53 per cent of the national crop. Their contribution to the 1993/94 crop is estimated at 63 per cent. In a further effort to increase cotton production, the CMB has launched an input credit scheme primarily for SSFs. In 1992/93 investment in the scheme amounted to about

Z$ 20 million. During 1993/94 about Z$ 65 million worth of inputs were provided by the scheme which benefited about 41230 farmers.

Wheat

Wheat is produced under winter irrigation largely by LSCFs who can afford the high costs of irrigation and mechanical harvesting. Limited production for domestic use is undertaken by SSFs using residual moisture rather than irrigation. Attempts to produce the crop under rainfed conditions have met with little success due to low yields and severe disease problems. National demand is about 400 000 tonnes but this level of production has yet to be achieved. Production in 1980 was 200 000 tonnes and declined to as low as 98 000 tonnes in 1983 due to a severe drought. The highest production of 325 454 tonnes was achieved in 1990. The 1993 crop was 276 119 tonnes with about 93 per cent being delivered by LSCFs and the remainder by SSCFs. The 1994 crop is expected to be similar.

Table 1**. Deliveries of Major Crops to Marketing Agencies, 1980 -1994**

Year	Maize (m tonnes)	Flue-cured Tobacco (x1000t)	Burley	Cotton (Tonnes)	Soyabeans (tonnes)	Wheat (tonnes)
1980/81	2.014	67 356	na	199 715	65 300	200 192
1981/82	1.391	89 388	na	154 482	84 300	212 945
1982/83	0.617	94 296	na	168 461	74 400	124 250
1983/84	0.942	119 636	5 146	240 244	89 800	98 505
1984/85	1.828	105 556	3 112	295 490	83 500	205 506
1985/86	1.594	114 304	2 645	248 251	85 000	248 300
1986/87	0.403	127 996	3 464	240 112	102 200	214 329
1987/88	1.120	119 918	3 734	323 268	122 673	256 912
1988/89	1.166	129 960	5 207	261 428	116 654	283 555
1989/90	1.120	134 378	5 893	187 613	105 210	325 454
1990/91	na	170 150	7 893	204 538	111 502	na
1991/92	na	195 162	10 188	59 871	41 955	na
1992/93	na	na	na	204 624	70 000	276 119
1993/94	2 100	170 000	na	178 375	110 000	280 000

* expected deliveries.
na: data not available to author

Soyabean

Soyabeans are an important cash crop in the large-scale commercial farming subsector but have yet to become established in the small-scale farming subsector. The crop is used primarily for the production of oil and stockfeeds. A small quantity of about 3 000 tonnes is purchased by the Harare-based Nutritional Research Company (NUTRESCO) for the production of various foodstuffs. The Commercial Oilseeds Producers Association (COPA) estimates total national demand at about 160 000 tonnes but this target has yet to be achieved. Production in 1980 was 65 300 tonnes and increased to an all time high of 122 000 tonnes in 1989. Since then, production has declined somewhat and is expected to be approximately 110 000 tonnes in 1993/94.

Sugarcane

Sugarcane is grown primarily for the production of sugar, a substantial amount of which is exported. In addition, the industry is responsible for the production of ethanol which is used in the formulation of blended fuel for widespread use in the country. The crop is produced mainly in the lowveld by three large estates, 50 LSCFs and 191 SSFs. Attempts are however being made to expand sugarcane production into the cooler higher altitude regions of the country. Average annual production is about 450 000 tonnes of refined sugar.

Sorghum and Millets

Sorghum, pearl millet and finger millet can be considered to be important food crops because they are better adapted to the more marginal conditions which are characteristic of natural regions IV and V. As such, these crops could play a major role in the food security of the large number of CAFs who reside in these areas. However, due to the widespread popularity of maize as a staple crop, these crops have not assumed the level of importance which they should occupy. Although their production in marginal areas has been actively promoted, CAFs in these areas continue to attempt maize production rather than rely on sorghum or millets as their main food supply.

Production of these small grains varies from 200 000 to 400 000 tonnes per year and accounts for about 15 per cent of calories available in Zimbabwe from cereal sources. Data on production of these crops are particularly weak and liable to wide margins of error because production is widely scattered in communal areas and only a small proportion of the crop is marketed through formal channels. Red sorghum is the only small grain of which a significant proportion is produced by LSCFs under contract to a brewing company.

Deliveries of sorghum to the GMB were 5 347 tonnes in 1984 and increased to 82 000 tonnes in 1986. Thereafter deliveries declined considerably with only 18 tonnes being delivered in 1992 after marketing of the crop was deregulated in 1991. As a result of the lack of interest in the crop and the declining output, Chibuku Breweries initiated a contract grower scheme to encourage production for its requirement of about 20 000 tonnes. The scheme was launched in 1990 and was initially restricted to LSCFs. At the outset only 15 farmers were contracted but the number has now grown to over 100. Participation by SSFs in the scheme has also increased and they presently provide about 10 per cent of the company's requirements.

Recent developments in the pricing of small grains are likely to have a major effect on the production of small grains. While the maize price is presently set at Z$ 900 per tonne, those of sorghum and the millets have been set at Z$ 520 per tonne. As a result, it will now be very difficult to encourage SSFs in the drier parts of the country to grow sorghum and millets other than for their limited domestic requirements. In the case of sorghum, only those farmers who are contracted to Chibuku Breweries, and thus receive a price which is comparable to that of maize, will continue to produce a marketable surplus.

Horticulture

Horticulture production is specialised and includes the following: vegetable production including traditional market gardening around urban centres; production of deciduous fruits such as apples, pears, peaches, nectarines and plums in the colder parts of the country; citrus production; viticulture of both wine and table grapes; cultivation of bananas and pineapples; and floriculture.

The horticulture industry is well established in Zimbabwe but has until recently been restricted to production to meet domestic demand. However, the industry deserves special mention due to the rapid development it has undergone in the last few years and the increasing role it now plays in the generation of foreign exchange. Since the liberalisation of the economy and the adoption of the structural adjustment programme in 1991, programmes tailored to make foreign currency available for export-oriented production have triggered a rapid and impressive expansion in the production and export of horticultural crops. Exports include cut flowers which consist largely of roses, citrus and fine vegetables. In 1993 citrus accounted for 54.5 per cent of exports, flowers 24.3 per cent, and fruit and vegetables 21.3 per cent. In the same year, exports increased by 22.3 per cent and earnings rose by 46 per cent to about Z$ 360 million. Exports are expected to increase by at least 37 per cent in 1994 with flower exports increasing by 20 per cent, fruit and vegetable exports by 108.4 per cent while citrus exports rise by 16.7 per cent. So impressive has been the growth in floriculture and fine vegetable production that horticulture has now become the fastest growing export-earning sector of the economy.

Other Crops

A wide variety of other crops are produced in both the large- and small-scale farming subsectors. Some are of little national importance but are nonetheless important to communal area households as a source of food and income.

Bambara nut is widely grown by CAFs in village gardens exclusively for domestic consumption. The crop has good nutritional qualities and thus serves as a good protein supplement. Production data is however not available.

Only two-rowed malting barley is produced in Zimbabwe under contract to the sole end-user, National Breweries. Like wheat, the crop is produced under winter irrigation almost exclusively by LSCFs. National requirement is determined by beer sales and is generally about 22 000 tonnes. The total requirement is about 35 000 tonnes, with the additional amount catering for malt exports to neighbouring countries.

Castor is a minor cash crop and is grown mainly by SSFs. Both annual and perennial types are produced, usually under contract to Trinidad Industries which utilises the oil in the production of a wide range of industrial products. Total demand is about 40 000 tonnes but has yet to be achieved.

Coffee is produced by both LSCFs and SSFs. The major part of the Zimbabwe crop is Arabica coffee and only a very small percentage is of the Robusta type. About 15 000 tonnes are produced annually and approximately 95per cent of the crop is exported.

Cowpea is one of the most important drought tolerant legumes grown in Zimbabwe. It is produced only by SSFs over an estimated area of about 20 00 hectares. It is traditionally intercropped with cereals such as millet, sorghum and maize, and serves as an important source of vegetable protein in the diets of communal farmers.

Groundnut is a major legume food and cash crop of SSFs who account for over 95 per cent of production. It ranks second after maize as the most widely grown crop and is the main source of plant protein in communal areas. Production is estimated at about 100 000 tonnes on an area of approximately 150 000 hectares. Total production for 1993/94 is expected to be about 70 000 tonnes with SSFs producing over 52 000 tonnes.

Sunflower is generally considered to be the poor farmer's crop which is ideally suited to marginal conditions, late planting and low input conditions. It is grown primarily for oil expression with the residue’s being used for poultry feed. The crop is presently grown predominantly by SSFs and SSCFs. It is estimated that output for 1993 will be approximately 74 000 tonnes.

The tea industry in Zimbabwe is relatively small in relation to the major world producers, accounting for less than 1 per cent of total world production. Production and processing is undertaken by five large commercial plantations located in the high altitude eastern districts and over 70 per cent of the crop is exported. However, over time, production has expanded to include numerous small-scale producers who sell their green leaf to the large organisations for processing. At present over 6 000 hectares are under cultivation. A record crop of 18 184 tonnes was produced in 1988/89 but since then production has declined somewhat primarily due to poor rainfall.

Pesticides in Zimbabwean Agriculture

Pesticide Legislation and Control

The use of pesticides in Zimbabwe is governed largely by the Pesticide Regulations of the Fertilisers, Farm Feeds and Remedies Act (Chapter III) and to some extent, the Hazardous Substances Act. The latter requires pesticides to be classified as to the hazard they pose whereas the former outlines the procedures to be adopted for the registration and use of any pesticide. Under the Pesticide Regulations all pesticides must undergo rigorous screening and registration before they can be imported and used in the country; the importation and use of unregistered pesticides is not permitted. Registration of pesticides is administered by the Plant Protection Institute of the DR&SS which oversees the importation and testing of experimental pesticides as well as pesticides which are destined for commercial use.

Another organisation which is involved in pesticide registration and the safe use of pesticides is the Agricultural Chemical Industry Association (ACIA). The association is composed of manufacturers and distributors of agrochemicals and animal health products and has been active for almost 30 years. The association promotes the safe and effective use of pesticides by producing training materials, distributing posters on safe pesticide use, and sponsoring participants and courses on safe pesticide use. The association also provides a forum for discussions on pesticide issues that might be of environmental concern in the country.

Pesticide Use and Availability

According to ACIA, over 200 different chemicals are used by Zimbabwean farmers. As to be expected, pesticide use is concentrated in the large-scale commercial farming subsector which is more sophisticated, better able to access resources that are required for the acquisition and application of pesticides, and largely based on intensive systems of crop production. Pesticide use in the small-scale commercial farming subsector is moderate. Amongst communal farmers who are confronted with a multitude of financial and other constraints, pesticide use is minimal except perhaps in cotton production where farmers are better informed and also sometimes provided with input packages which include pesticides.

Exact figures on the quantities and value of pesticides used are difficult to obtain and vary considerably from year to year depending on the nature of the season. However, it is estimated that in 1993 Zimbabwean farmers spent about Z$ 290 million (US$36.3 million) on chemical inputs of which about 40 per cent were insecticides, 20 per cent herbicides, about 20 per cent fumigants, approximately 10 per cent fungicides with the remaining 10 per cent being other chemicals such as growth regulators. Tobacco is a major user of chemicals given that it has large requirements for fumigants and suckercides, and therefore accounts for about 40 per cent of the total value of all chemicals used according to information obtained from Agricura. Maize, soyabeans and cotton account for about 15 per cent each while horticulture accounts for the remaining 15 per cent. According to the CFU, tobacco accounts for approximately 60-65 per cent of chemicals used, maize and cotton about 15-20 per cent each and the remaining crops approximately 15 per cent.

The economic policies of government and the system for acquisition of imported chemicals has influenced pesticide availability considerably. Prior to liberalisation of the economy importation of agrochemicals was restricted to registered agrochemical companies and strictly controlled due to the stringent controls on foreign exchange. In order to qualify for a foreign currency allocation for the purchase of chemicals, agrochemical companies had to furnish details of estimated requirements of essential pesticides as well as sufficient evidence to justify their claims. This cumbersome procurement system was necessitated by the strict government controls on the economy and resulted in considerable delays in procurement and widespread shortages. After 1989 and before the adoption of the structural adjustment programme, the acquisition of essential chemicals was relaxed somewhat and placed under an Open General Import Licence (OGIL) scheme which was designed to allow for easier procurement of essential materials. Although this system improved pesticide procurement considerably, it did not entirely eliminate the problem of shortages. With the advent of the economic structural adjustment programme in 1991, import and foreign exchange controls were further relaxed thus paving the way for easier procurement of agrochemicals. Since then, anyone can register as a sales agent for agrochemicals and import as much as they like provided funds are available for the purchase of the required foreign exchange. It is envisaged that market forces will determine what and how much will be imported and eventually stabilise the importation of pesticides. However, recent shortages indicate that the system of procurement of agrochemicals is yet to stabilise. Further complications have arisen because some commodity organisations such as the CMB and Zimbabwe Tobacco Association have decided to procure their own agrochemicals in an effort to reduce costs and ensure timely acquisition for their members. Clearly, the system for pesticide procurement is still in a state of flux and will require that commodity associations and agrochemical companies work out agreeable arrangements which will ensure that the country's pesticide requirements are fully met.

Very few developments have occurred in policies which affect the use of pesticides. The most notable changes include the banning of DDT and the declaration of controls on the use of acaricides and synthetic pyrethroids.

Incentives for Reduced Pesticide Usage

The inflationary effect of rapid devaluation has resulted in spiralling input costs and vastly increased the need for prudent pesticide use. In addition, liberalisation of the marketing of most agricultural commodities and uncertainty over prices has contributed to increasing awareness of the need for commercial farming to be undertaken in a more business-like manner. Accordingly, LSCFs are adopting measures to reduce their input costs without necessarily jeopardising their crops. Although the effects of these developments are yet to manifest themselves as reduced pesticide usage, it is likely that the rapidly rising costs of production will force farmers to adopt a more prudent approach. SSFs have probably been more affected by spiralling input costs due to their reduced ability to secure financing. As a result, it is very likely that, except in instances where pesticides are supplied as part of an input package, they too will reduce their pesticide use considerably.

The occurrence of situations which questioned the continued viability of chemical control of serious pests has also contributed to the adoption of more rational pesticide use. Two well known examples illustrate this effect. One, resulting from studies carried out in the 1970s by the Cotton Research Institute, concerned the development of resistance to commonly used acaricides by red spider mites (*Tetranychus urticae*). This resulted in an enforced acaricide spray rotation scheme which is still in place today. More recently, considerable concern has been expressed about the indiscriminate use of synthetic pyrethroids particularly in the fledgling horticultural industry. As a result "pyrethroid restriction periods" have been implemented across the country.

The negative impact of pesticide residues on the marketability of agricultural products is well known in Zimbabwe and likely to become more important as the country attempts to increase its exports in line with its economic reform programme. The most noted pesticide residue awareness and control is apparent in the tobacco industry where about 98 per cent of the crop is exported. Tobacco farmers are strongly advised to adhere to recommended practices and strict routine checks on pesticide residues are undertaken to ensure that the crop is not rejected by importing countries. Increasing awareness of the negative impact of pesticide residues is also apparent in the rapidly expanding horticultural industry.

Increasing awareness of the value of integrated pest management and biological control is also contributing to reduced pesticide use in some crops. Examples include the well established and widespread use of nuclear polyhedrosis virus for the control of looper caterpillars in soyabeans and the more limited use of predatory mites (*Phytoseilius* spp.) for control of red spider mites in strawberries, hops and other horticultural crops. Commercial farmers now appear more amenable to suggestions on the use of biological control and integrated pest management. This is probably attributable to a number of reasons, including concerns over rejection of produce due to unacceptable residue levels and the need to reduce input costs.

In general, environmental issues and concerns have not as yet featured as a major incentive for reduced pesticide use in Zimbabwe. Although some LSCFs who are the major users of pesticides have demonstrated an increasing awareness of environmental issues, there is little or no indication that this has encouraged them to reduce their pesticide use. There appears to be a widely held belief among commercial farmers that proper pesticide use in accordance with recommendations poses little or no environmental threat because the climate in Zimbabwe is conducive to rapid chemical breakdown.

Environmental Monitoring

Environmental monitoring for pesticide residues has been carried out in Zimbabwe since the early 1980s and is an important activity in the Chemistry and Soil Research Institute of the DR&SS.

In general, the environmental monitoring carried out in Zimbabwe indicates that although several pesticide residues are present in the environment, the levels are comparatively low and well below permitted levels for consumption. However, the long-term ecological consequences of the residue contamination remain unknown. Although detailed residue analysis and long-term ecological studies have not been carried out in areas with a heavy concentration of high-input commercial farming, it appears that pesticide use does not as yet pose a serious environmental threat in the country.

III. CROP RESEARCH, TECHNOLOGY DEVELOPMENT AND DIFFUSION

Crop research in Zimbabwe is undertaken by various public-sector, parastatal and private-sector institutions. A very limited amount of adaptive research is also carried out by non-governmental organisations. A considerable amount of the research is based on a collaborative effort between public- and private-sector institutions.

Public-Sector Institutions

All public-sector research is co-ordinated by the Agricultural Research Council (ARC) which serves as an advisory body to the MLAWD. The ARC is comprised of representatives from the CFU, ZFU, UZ, the Agricultural Development Authority (ADA), and the Directors of DR&SS, AGRITEX and TRB. Overall responsibility for public-sector crop research resides with DR&SS.

Department of Research and Specialist Services

DR&SS was established in 1948 and is responsible for research in crop and livestock production as well as providing advisory and specialist services to the agricultural industry. It is organised into three main divisions; crops, livestock and pastures, and seed services. Its research mandate is executed under its institutes of Crop Breeding, Agronomy and Farming Systems, Plant Protection, Chemistry and Soil Research, Seed Services, Horticultural Research and Cotton Research. The activities of these institutes are supplemented by 17 research stations located throughout the country. Prior to independence in 1980, the department provided research, advisory and technical services primarily for the large-scale commercial farming subsector. However, after independence it was directed by government to focus its efforts on the needs of communal farmers.

In addition to its research functions, the department provides advisory services for crop and livestock production as well as pest and disease control. It also provides regulatory services for fertilisers, farm feeds and remedies, Plant Breeders Rights, seed production, phytosanitary control, agricultural pesticide registration, and pest control for cotton and tobacco. Its technical services include pesticide residue analysis, fertiliser recommendation, surveys on crop-loss assessment, milk recording schemes and the manufacture of legume inoculant.

The activities of the department are funded primarily by government. Other sources of funding include national commodity associations, the World Bank, the British Overseas Development Administration (ODA), the Danish International Development Agency (DANIDA), United States Agency for International Development (USAID), IITA, European Union (EU) and Kellog Foundation. Government expenditure on agricultural research has declined considerably over the years. During the 1960s and early 1970s approximately 20 per cent of the Ministry of Agriculture's budget was allocated to DR&SS. However, by the mid-1980s this figure had fallen to below 5 per cent and has since been maintained at this low level. During 1989/90 the budget allocation to DR&SS was Z$ 19.515 million (US$8.596 million) but increased by 21.6 per cent to Z$ 24.9 million (US$9.444 million) in 1990/91 and a mere 4.4 per cent to Z$ 25.754 million (US$5.754 million) in 1991/92. Therefore, expenditure on agricultural research in real terms has declined appreciably. The marked decrease of 45.5 per cent in US$ terms between 1990/91 and 1991/92 is attributable to a marked decline in the value of the Zimbabwean dollar from 0.379 to 0.20.

Parastatals

Tobacco Research Board

The TRB was reconstituted as a statutory body in 1950 to supplement government research. Since then, this organisation has assumed total responsibility for all research on tobacco. It is funded by both government and tobacco growers and possesses some of the best research facilities in the country. Its work encompasses investigations on all aspects of flue-cured, burley and Oriental tobacco production, and previously included studies on cigar and dark fire-cured tobacco as well. It conducts research in breeding, biotechnology, agronomy, physiology, curing and engineering, pathology, nematology, soil science and chemistry. The Board possesses perhaps the most advanced and organised biotechnology research programme and ranks as the first research institute to establish a biotechnology department.

Private-Sector Institutions

Private-sector institutions engaged in crop research in Zimbabwe include local companies and affiliates of externally based companies. The local institutions comprise the Zimbabwe Sugar Association Experiment Station, the Agricultural Research Trust (ART) and the Rattray Arnold Research Station of the Seed Co-op. Externally based companies operating in Zimbabwe are primarily the seed companies Pioneer, Cargill and Pannar.

The Zimbabwe Sugar Association Experimental Station which is independently funded by the sugar industry was established in 1966 to investigate problems associated with sugarcane production under irrigation in the south-eastern lowveld of the country. In addition to its research activities, the station provides disease inspection, sucrose analysis and fertiliser advisory services for its members.

The ART was established in 1981 primarily to serve the interests of the large-scale commercial farming subsector when it became apparent that after independence, government research would concentrate on the needs of SSFs. The trust is an independent research, demonstration and training organisation. It consists of a self-supporting commercial section which produces livestock and an assortment of crops, and a research section which is heavily subsidised by LSCFS. The research unit undertakes contract research on behalf of various commodity organisations and companies, and also collaborates with government research in the testing of wheat and maize varieties.

Rattray Arnold Research Station was established in 1974 by the then Zimbabwe Seed Maize Association and is today the main research station for Seed Co-op, the largest seed production company in the country. It is engaged mainly in breeding work with the crops of interest being maize, wheat and soyabeans. Limited testing of varieties of barley and sorghum is also undertaken. The research station enjoys a very close working relationship with DR&SS as well as some IARCs. It undertakes several maize and wheat trials on behalf of government research and regularly receives maize and wheat germplasm from CIMMYT. The station also has a close working relationship with the DeKalb seed company in the United States.

Pioneer Hybrid International was established in Zimbabwe in the mid-1980s and initially concentrated its efforts on germplasm enhancement with a view to entering the hybrid maize market at a later stage. As a result, it has only recently made its material available for testing and is currently offering some of its hybrids on the market. The company has established a seed processing facility and has also entered into an agreement with the ZFU to undertake agribusiness ventures in the country.

The giant transnational Cargill established a presence in Zimbabwe in 1991 and initially only undertook the testing of its maize hybrids which had been developed elsewhere. Since then, it has set up a small experimental station and a modest seed-processing facility. Its major interest is in the development of maize hybrids. However, it also has interests in sunflower and sorghum and has introduced some of its material for testing in the country.

Pannar is a South African-based plant breeding and seed company which has been operational in Zimbabwe since 1982. Its interests include white and yellow maize, hybrid sunflower, hybrid red and white sorghum, and forage sorghum and millet. However, its major thrust is in hybrid maize, particularly for the more marginal areas located in Natural Region III. The company does not have a locally based breeding programme and is engaged only in the widespread testing of varieties developed in South Africa. It presently commands about 20 per cent of the hybrid maize seed market and has recently established a moderate size seed-processing facility.

International Agricultural Research Centres

Although Zimbabwe enjoys a very close working relationship with a large number of IARCs, only two of these centres have established research facilities in the country. These include the International Centre for Maize and Wheat Improvement (CIMMYT) based in Mexico, and the International Centre for Research in the Semi-Arid Tropics (ICRISAT) which is headquartered in India. The CIMMYT research station is responsible for mid-altitude maize research and is largely committed to germplasm enhancement rather than variety release. The SADC/ICRISAT research station carries out research on sorghum, pearl millet and finger millet specifically for the drier areas of Zimbabwe and other countries of the Southern Africa Development Community (SADC).

Plant Breeding, Seed Production and Distribution

Zimbabwe has a long history of organised plant breeding, seed certification and production. As a result, the country has established a good reputation, notwithstanding some difficulties, in seed production and distribution, and is widely regarded as an outstanding example and generally reliable supplier of high quality seed of several crops.

Breeding Programmes and Variety Release

A large number of plant breeding programmes exist in Zimbabwe. They cover a wide range of crops and are executed by both the public and private sectors as well as parastatal organisations. The major breeding programmes and their executing agencies are listed in Table 2.

The oldest and largest plant breeding establishment is the government-owned CBI of DR&SS. The institute is responsible for breeding programmes in maize, sorghum, wheat, barley, soyabeans, sunflower, cowpeas, pearl millet, finger millet, potatoes, groundnut, beans and bambara nut. In addition to the execution of conventional breeding programmes, the institute is also engaged in variety evaluation for triticale, oats and rapeseed but does not have structured breeding programmes for these crops. For the execution of its breeding programmes, particularly nation-wide variety testing, the institute has developed a close working relationship with private research organisations such as ART and the Seed Co-op's Rattray Arnold Research Station.

The CBI is closely associated with the seed production system in the country in accordance with agreements reached between government and the seed associations, in particular the Seed Co-op. As such, the institute is responsible for maintaining breeders seed of its varieties but releases its seed free of charge to selected seed associations which are signatories to the agreement. The responsibility for the multiplication and distribution of varieties developed by the public-sector breeding programmes thus resides with registered seed associations. At present the Seed Co-op is the sole signatory to the agreements with government and is thus the only company which is allowed to obtain and multiply government-bred varieties. However, efforts are underway to alter the agreements so as to allow other companies to bid for the multiplication and distribution of varieties developed by the CBI. Although the institute holds Plant Breeders Rights for all its released varieties, it does not receive royalty payments from the seed associations.

The institute has close links with IARCs such as CIMMYT, CIP, ICRISAT, CIAT and IITA and regularly receives considerable amounts of germplasm from these centres. In addition, it is responsible for evaluation of various germplasm nurseries emanating from the IARCs and thereby contributes to international variety testing particularly for maize, wheat and barley. In view of its long-standing and close working relationship with several IARCs, the CBI is well positioned to exploit biotechnology innovations emanating from such centres.

Its sister organisation, the Cotton Research Institute (CRI) is responsible for cotton breeding. However, unlike the CBI, the CRI does not release its varieties to seed associations for multiplication and distribution. This responsibility is accorded instead to the CMB which contracts out seed production to selected growers.

Tobacco breeding is undertaken by the TRB, a parastatal organisation which is solely responsible for research on tobacco. Virtually all tobacco production in Zimbabwe is based on varieties and hybrids developed by the TRB. The TRB carries out limited commercial seed production of male-sterile hybrids while the Zimbabwe Tobacco Seed Association is responsible for multiplication and distribution of all other varieties developed by the TRB.

In addition to the public-sector, there are various private-sector initiatives in plant breeding. The local Seed Co-op company is engaged in the breeding of hybrid maize, soyabeans and wheat as well as evaluation of sorghum and barley varieties. Pioneer International and Cargill have established local breeding programmes as well as seed production facilities. Both companies are concentrating on the development of maize hybrids but also have interests in the evaluation of sorghum and sunflower. Pannar does not carry out any breeding work in Zimbabwe and is engaged mainly in the evaluation of South African-bred maize hybrids and varieties of sorghum, sunflower and vegetables for adaptation to local conditions. A small breeding programme on castor is being carried out by a local company, Trinidad Industries, working closely with DR&SS.

Two breeding programmes are executed by IARCs. ICRISAT, in co-operation with the Southern Africa Development Community (SADC), is engaged in the breeding of sorghum, pearl millet and finger millet, primarily for the drier areas of Zimbabwe and the SADC region. CIMMYT has established a small research station for the development of mid-altitude maize germplasm. While the objectives of SADC/ICRISAT include germplasm development as well as variety development and release, the activities of CIMMYT are, as for its parent institution in Mexico, restricted to germplasm development only.

It is relevant to note that virtually all the breeding programmes in Zimbabwe are based on conventional breeding procedures. While some of the programme operators have expressed very keen interest in utilising biotechnology techniques to enhance variety development, they are yet to implement such strategies. To date only the TRB has implemented a biotechnology research programme which is designed to complement its conventional breeding programme.

Official release of new crop varieties is administered DR&SS. For this purpose, the department convenes a Variety Release Committee of relevant experts to review all proposals for release of a new variety. Before any variety can be released, specified criteria relating to its origin, characteristics and performance must be satisfied before the committee can recommend that it be registered as new variety.

Table 2. **Main Plant Breeding Programmes in Zimbabwe**

Crop	Year begun	Responsible organisation
Bambara nut	1990	DR&SS
Barley	1956	DR&SS
Beans	1984	DR&SS
Cassava		UZ; DR&SS
Castor	1989	Trinidad Industries; UZ
Cotton	1925	DR&SS, CRI
Cowpea	1989	DR&SS
Finger millet	1988	DR&SS
	1985	SADC/ICRISAT
Groundnuts	1970	DR&SS
Maize	1932	DR&SS
	1974	Seed Co-op
	1986	Pannar Seed Company
	1988	Pioneer International
	1990	Cargill
		CIMMYT
Pearl millet	1977	DR&SS
	1985	SADC/ICRISAT
	1987	ENDA-Zimbabwe
Potato	1957	DR&SS
Sorghum	1969	DR&SS
	1985	SADC/ICRISAT
Soyabean	1963	DR&SS
	1982	Seed Co-op
Sunflower	1975	DR&SS
	1988	Pioneer International
	1990	Cargill
	1986	Pannar Seed Company
Tobacco	1953	Tobacco Research Board

Plant Breeders Rights

All plant breeders are entitled to apply for local protection of their released varieties under the Plant Breeders Rights Act which is administered by the DR&SS. The Act enables an individual or organisation to register a new variety or hybrid bred inside or outside Zimbabwe provided the variety or hybrid has been officially released and thus recognised as a new variety or hybrid. In order to obtain a licence from the Registrar of Plant Breeders Rights, the breeder has to supply information which demonstrates that the variety or hybrid is new, uniform and distinct. Information on origin, breeding methods, performance and morphological characteristics is also required. Once granted, the rights allow for local protection of the variety or hybrid for a period of 20 years, with possible extension for 5 years. However, any person may use protected material as an initial source for breeding new varieties provided that such material is not used in a repetitive manner as in the production of hybrid seed.

Seed Certification, Production and Distribution

In general, Zimbabwe possesses a fairly sophisticated and efficient seed certification and production system which is comparable to those in developed countries. The basic principles for ensuring that the seed industry produces high quality seed are laid down in the Seed Act of 1965. The Act empowers the Minister of Agriculture to make regulations for the production of quality seed. Under the Seed Regulations of 1971, the Minister has outlined technical regulations and standards for seed production. These include conditions and standards for purity and germination tests as well as the requirements for importation and export of seed. In addition, the government of Zimbabwe has recently become signatory to the international agreement on compulsory seed certification. As a result, all seed offered for sale in future will have to be certified. The move is intended to ensure that all seed purchased by farmers is of the highest quality and true to its identity. However, it is likely that the management and implementation of compulsory seed certification will pose several problems, particularly for the Seed Services Unit which is already unable to fully implement its seed inspection and certifying mandate.

The main seed certifying authority is the Seed Services Unit of the DR&SS which is responsible for inspecting most seed crops and carrying out required tests for certification. In addition, other agencies which are considered to have sufficient equipment, expertise and experience to enable them to carry out the required testing have been granted the authority to act as seed certifying agencies. These include the Seed Co-op which is the largest seed producer, the CMB and Forestry Commission.

In accordance with international practice, a system of production of breeders seed, foundation seed and certified seed has been adopted for most crops. Under this system individual breeders are required to produce and maintain the embryonic breeders seed on which all seed production is based. This seed can only be distributed to selected foundation seed growers through seed certifying agencies. Foundation seed is produced under close supervision of the Seed Services Unit and seed certifying agencies. Thereafter it is issued to registered certified seed producers who are also closely monitored and required to produce certified seed in accordance with specified regulations.

Seed production of varieties developed by public-sector-breeding programmes is governed by what are commonly referred to as the tripartite agreement for maize, and bipartite agreements for sunflower, wheat, barley, soyabeans, groundnuts and sorghum. These agreements between Government and Seed Co-op, the main seed growers association, lay down the essential conditions for seed production. Under this system, the Government retains Plant Breeders Rights over all new varieties developed at publicly funded institutions but agrees to release them free of charge to Seed Co-op for multiplication and distribution. To allow for organised seed supply, a production schedule is developed annually and agreed upon by the Government, the CFU, and the seed associations so as to ensure that the country's demand for seed is met. Furthermore, the seed associations are required to produce sufficient seed to allow for maintenance of a 20 per cent buffer stock which is designed to ensure sufficient seed supply in the event of a bad season.

The Seed Co-op functions as a seed certifying agency and is also the largest producer of seed in the country. Formed in 1983 as a result of a merger between the Zimbabwe Seed Maize Association and the Zimbabwe Horticultural Crop Seed Association, membership is restricted to LSCFs. The Co-op possesses a well developed seed production and distribution network particularly for hybrid maize, soyabean, wheat, barley and to some extent groundnuts and sunflower. Other seed production organisations include the Zimbabwe Pastoral Seed Growers Association formed in 1953 and the Zimbabwe Seed Potato Association (ZPSA) formed in 1955. The Zimbabwe Pastoral Seed Association is primarily responsible for the production of grass seed and has attempted to establish a certification scheme for the production of seed of sub-tropical grasses. The Zimbabwe Potato Seed Association produces virus-free planting material in selected cool and high-altitude areas of the country where transmission of viral diseases is non-existent.

In the case of tobacco, seed production is undertaken by the Zimbabwe Tobacco Seed Association (ZTSA) which was formed in 1958. Until recently the ZTSA was the sole producer of tobacco seed. However, the TRB has recently ventured into the commercial production of limited quantities of male-sterile hybrid seed.

The production of cotton seed is undertaken by the CMB which contracts out seed production to selected registered growers. Distribution is efficiently effected through the numerous CMB depots which are located throughout the main cotton growing areas. This system of distribution has proved to be effective, particularly for the numerous small-scale cotton growers who would otherwise experience considerable difficulties in acquiring seed due to their physical isolation in communal areas.

More recently, private companies as well as transnationals have entered the seed market as producers and distributors of improved varieties. These include the local company National Tested Seeds, the South African-based company Pannar, and the giant transnationals Pioneer Hybrid International and Cargill.

Limited seed production is also undertaken by non-governmental organisations. The most notable example is the small grains seed project of the ENDA. The project is designed primarily to meet the needs of resource-poor farmers located in marginal areas. As such, its target crops are the drought-tolerant small grains such as sorghum, pearl millet and finger millet. The project has succeeded in the collection and multiplication of local landraces to the extent that ENDA has been contracted to produce seed for the Seed Co-op.

The adequacy and level of seed production and distribution for the different crops varies considerably and is a matter of concern for some crops. Differences in sufficiency of production are probably attributable to the importance of the crop, volume of sales and expected returns from sales. Production of hybrid maize seed is highly organised and attracts great interest from both seed associations, breeding companies and seed producers. As a result, supply of hybrid maize seed is generally assured although not all growers may be able to acquire the types and quantities they require. Furthermore, the distribution network for hybrid maize seed is well developed and hence enables most farmers, both large and small-scale, to obtain their seed. Production and distribution of tobacco, soyabean and cotton seed is also well organised and thus allows for most farmers to acquire the varieties and quantities they require. The major area of concern is in the production and distribution of seed of the less important crops which are primarily grown by SSFs. These include groundnuts, sunflower, sorghum, pearl millet, finger millet, cowpeas and bambara nut. For these crops, production and distribution of high quality seed are still beset by problems which have hampered production considerably. The main reason for the problems in seed production and distribution is probably the unattractiveness of these crops to seed associations and producers. As a result, a special effort is required to ensure that adequate quantities of improved varieties of these crops are made available to SSFs.

In general, the level of sophistication and development of the seed production and distribution system in Zimbabwe offers good prospects for the diffusion of biotechnology innovations delivered via improved seed. Such prospects are best for the important crops (i.e. tobacco, cotton, wheat, barley and soyabeans) which are produced by LSCFs as well as maize which is grown by most SSFs. For these crops, the system of seed production and distribution is well developed and thus able to cater for the needs of most farmers. Furthermore, most farmers including those in the small-scale subsector are aware of the importance of improved seed in the production of these crops. They would therefore be willing to seek and adopt improved transgenic cultivars provided their advantages are adequately demonstrated and vigorously promoted, and the cost of such seed is not considered to be exorbitant and unjustified. For LSCFs who are more cost conscious, adoption of such seed would be heavily dependent on its cost relative to the savings that can achieved through reductions in the use of agrochemicals. On the other hand, for SSFs who are not as aware of costs and profits, and are also not major users of agrochemicals, adoption and diffusion of transgenic cultivars is likely to be more problematic if seed costs of such cultivars are considerably higher than those of conventional non-transgenic cultivars. The inability of most SSFs to fully comprehend and appreciate the costs and benefits of adopting transgenic cultivars is therefore likely to pose a major constraint to the adoption of seed-transmitted biotechnology innovations. In contrast, the unsatisfactory situation with regard to seed production and distribution of less important crops such as groundnuts, sunflower, sorghum, cowpeas, bambara nut, pearl millet and finger millet is likely to pose a serious limitation to the adoption and diffusion of biotechnology innovations unless a special effort is made to address these problems.

Genetic Resources Policies and Activities

Although plant breeding programmes have been operational in Zimbabwe for several years, no formal genetic resources policies have been enunciated until recently. Individual breeding programmes have been solely responsible for acquiring and storing their own germplasm and no specific policies were formulated for the collection and documentation of indigenous plant genetic resources.

The emergence of a national and regional genetic resources policy emanated from realisation that the member states of SADC need to preserve indigenous genetic resources in the region and share them for the common good of all member states. As a result, the member states agreed to embark on a comprehensive programme for the conservation of plant genetic resources under the auspices SACCAR. The programme called for the establishment of a regional genebank as well as national genebanks in each member state. As a result, the SPGRC was established in Zambia in 1991 with the assistance of the Nordic Genebank and funding from the Nordic countries. It was intended that national genebanks should be established thereafter and that these genebanks should work in close collaboration with the SPGRC. As a result, the NGBZ is presently being established by the Seed Services department of the DR&SS, with responsibility is to collect, document, characterise and evaluate genetic resources within the country.

Other genetic resources activities in Zimbabwe include the following:

- Collection and documentation of tobacco landraces by the TRB. Initial collections were undertaken in the 1950s and led to the discovery of material with some resistance to the rootknot nematode (*Meloidogyne javanica*), a common and serious pest of tobacco. Further collections were carried out in 1987-89;

- Collection and documentation of indigenous sorghum landraces by the DR&SS and ICRISAT;

- Collection and documentation of indigenous cowpea landraces by the IPGRC;

- Collection and testing of landraces of sorghum and pearl millet by the NGO ENDA.

Technology Transfer, Adoption and Diffusion

The diffusion of agricultural technology in Zimbabwe is accomplished through extension and advisory services provided by the public and private sectors as well as non-governmental organisations. Non-market mechanisms mediated through public-sector and non-governmental organisations provide the most appropriate channels for technology diffusion to the numerous CAFs who are scattered across the country. For LSCFs, both market and non-market mechanisms are relevant to technology diffusion.

The Department of Agricultural Technical Extension Services (AGRITEX) of the MLAWD provides extension services for most of the farmers in the country. Prior to independence in 1980 extension services were provided mainly for LSCFs while services for SSFs left a lot to be desired. Since 1980 though, AGRITEX has substantially expanded its services and coverage of SSFs located in communal areas. However, it still continues to provide services to LSCFs on a request basis. Although the extension services for SSFs have improved considerably since independence, AGRITEX continues to be constrained by inadequate resources and personnel. The present extension worker:farmer ratio of 1:800 is unacceptable and hampers effective technology transfer and diffusion for those who need it most.

Private-sector agencies engaged in crop production technology diffusion or extension include agrochemical companies involved in the marketing of fertilisers, pesticides and herbicides, as well as companies that have operations which are dependent upon supply of a specific crop from farmers. The latter primarily provide advisory services for both large and small-scale farmers who are contracted to the companies whereas the former generally provide advisory services to LSCFs who are the major purchasers of agrochemicals. Examples of companies which provide advisory services due to their reliance on specific crops include the following: Astra Corporation which has interests in the production of paprika; Olivine Industries which is promoting the production of Michigan pea bean; Trinidad Industries with interests in castor bean production; and Delta Corporation which contracts out the production of hops and malting barley for its subsidiary National Breweries.

A number of non-governmental organisations are engaged in development projects for SSFs and could therefore assist in the transfer and diffusion of biotechnology innovations to these farmers. They include ENDA, the Catholic Development Commission (CADEC), the Belgian organisation COOPIBO, the Lutheran World Foundation, the Organisation for Rural Associations for Progress (ORAP) and the Jesuit organisation Silveira House. The ability of such organisations to facilitate the diffusion of technology has now been considerably improved following changes in the lending policy of the AFC, the major financial supporter of SSFs. Recent policy changes now make it possible for NGOs to borrow money from the AFC for the funding of specific projects being undertaken by SSFs. This policy change could greatly improve the ability of resource-poor farmers to access new technologies which they would otherwise be unable to obtain and utilise.

In general, adoption and diffusion of biotechnology innovations by LSCFs is unlikely to be problematic provided the economic benefits of such innovations are clearly evident. However, conflict of interest from agrochemical companies who provide most of the advisory services for such farmers and are also dependent on the sale of agrochemicals to these farmers could hamper the promotion of the adoption and diffusion of biotechnology innovations which are designed to reduce the use of agrochemicals. As such, research personnel may have to play a more active role in publicising the full benefits of biotechnology innovations so as to counter negative feedback from agrochemical companies who have vested interests in agrochemicals and more extensive contact with LSCFs. In contrast, the adoption and diffusion of biotechnology innovations by SSFs is likely to be a more daunting task requiring the marshalling of all possible mechanisms for the promotion of technology transfer and diffusion. An essential starting point will require that extension personnel and relevant NGOs be fully informed on the application and value of biotechnology innovations which are intended for adoption by SSFs. The cost of biotechnology innovations will also require very careful consideration.

IV. BIOTECHNOLOGY IN ZIMBABWE

National Policy and Strategies

National policy for science and technology is primarily formulated by the RCZ which was appointed in 1984. The activities of the Council are governed by an act of parliament which was passed in 1986. The operational arms of the Council are its eight standing committees on agricultural science, earth sciences and mineral resources, industrial development, informatics, medical sciences, natural and environmental sciences, remote sensing and social sciences.

The role of the RCZ is to:

- advise government on areas of science policy and other matters relating to science and technology;
- co-ordinate research in the country;
- co-ordinate the activities of other research councils and institutes; and
- vet foreign researchers and research proposals.

Biotechnology policy for Zimbabwe is briefly covered under the policy statement on science and technology drafted by the RCZ. The current policy document which is still in draft form was prepared by the RCZ after deliberations at its third consultative meeting held in 1990. At that meeting, the standing committees of the council consulted a wide range of experts in the relevant fields in an attempt to draw up a clearly defined policy for science and technology. The draft policy document emphasises that promotion of the right type of technology is crucial for success in agriculture where the main objective of research is to achieve and sustain self-reliance in food supply. The broad priority areas of policy for agriculture are:

- sustainable and economic crop and livestock production;
- plant and animal breeding to produce varieties and breeds adapted to various environments; and
- biotechnology for crop and livestock improvement and expansion of the genetic stock base.

Although the national policy and strategy for biotechnology has not been fully developed and enunciated, the elements of a national policy and strategy are being pursued. Of particular note are the initiatives in manpower development, research and biosafety.

In view of the realisation that adequately trained manpower is essential for the execution of a local biotechnology research and development programme, considerable effort is being made to ensure that the required critical mass of scientists is achieved. Support for manpower development includes the training of M.Sc. level biotechnologists at the UZ with assistance from the Swedish Agency for Research Co-operation with Developing Countries (SAREC) and the Dutch government. Further postgraduate training at the Ph.D. level is being pursued by the SIRDC so as to develop a cadre of adequately trained personnel to carry out the activities of the Biotechnology Institute.

The establishment of the Biotechnology Institute in the SIRDC by the RCZ is a clear indication that biotechnology research is being accorded a high priority in the national science and technology agenda. Given that a considerable portion of the funding of the Centre is being provided by government, this demonstrates that the Zimbabwean government is committed to the establishment of a national science and technology centre which will spearhead science-led development. Furthermore, it is apparent that the biotechnology research programme is intended to complement and work closely with established conventional research programmes.

It is apparent that the issue of biosafety is being given serious consideration. RCZ and SIRDC, with the assistance of the DGIS of the Dutch government are presently actively engaged in the formulation of satisfactory biosafety mechanisms. Although overall national policy on biosafety is yet to be clarified, considerable progress has already been made in the development of biosafety guidelines for the country.

It is important to note that the draft national policy and strategy on biotechnology is somewhat vague and refers only to the promotion of biotechnology for crop improvement in general and expansion of the genetic base available to breeders. No specific mention is made of the application of biotechnology to address environmental concerns.

National Programmes and Priorities

The important national programmes in biotechnology include those being undertaken by the national agricultural research system (NARS) and the recently formed SIRDC. The programmes of the NARS include legume inoculant production and development of tissue culture techniques for horticultural crops.

Legume inoculant production has been in progress since 1962 and has until recently been targeted largely to meet the needs of LSCFs. The programme represents the first successful commercial application of biotechnology and has a long history of success in the large-scale commercial farming subsector. The expansion of this programme to meet the needs of SSFs is now accorded a high priority because the technology can be readily utilised by these farmers and contribute to the alleviation of their fertiliser shortage problems. Furthermore, the production and domestic use of soyabean is viewed as an important contribution to the improvement of the nutrition of SSFs and their families.

The development of tissue culture techniques to facilitate importation of disease-free in vitro germplasm and rapid propagation of planting material is presently being assigned a high priority by the HRC of DR&SS. The main purpose of this project is to ensure that Zimbabwe is in a position to fully participate in the importation of improved horticultural germplasm from around the world without jeopardising the local industry through the introduction of contaminated material. In view of the widespread distribution of germplasm in an in vitro form, it is considered essential that local capacity and capability in tissue culture be developed so as to enable the country to acquire improved and disease-free horticultural germplasm.

Broad priority areas identified for the Biotechnology Institute of the SIRDC are:

- development of commercial-scale micropropagation systems for important vegetatively propagated crops which are primarily grown by SSFs. Targeted crops include sweet potato, Irish potato and possibly cassava;

- research into applied plant and animal genetics designed to supplement conventional plant and animal improvement techniques. Of particular note is the development of crop varieties which are suited to marginal areas and are primarily grown by resource-poor farmers;

- development of expertise and techniques in food processing; and

- development of new diagnostic tools and vaccines for animal and human health.

The programmes supported by the Special Programme in Biotechnology of the DGIS are solely designed to meet the needs of resource-poor SSFs. The emphasis on SSFs emanates from the belief that unless their needs receive special attention, they are likely to be bypassed and perhaps even seriously disadvantaged by developments in biotechnology. A deliberate exercise has been undertaken to identify priority areas for this programme. In the 1993 study on "Biotechnology for Resource-Poor Farmers: Crop Production Constraints, Institutional Biotechnology Capacities and Priorities" broad priority areas were first identified on the basis of the most important constraints which limit crop production by resource-poor farmers. Thereafter, specific crops were given priority on the basis of their importance in the small-scale farming sector.

The major constraints to crop production in the small-scale farming sector, in order of importance, were identified as drought, unavailability of fertilisers, pests and diseases, and weeds, especially Striga in sorghum and maize. As such, it was recommended that if possible, biotechnology research should strive firstly to address the debilitating effects of drought which frequently adversely affects crop production throughout the country. Secondly, biotechnology intervention should attempt to alleviate the problems associated with the unavailability of fertilisers to SSFs who do not have the financial resources to acquire high cost inputs.

Thirdly, biotechnology solutions should be sought for the various pests and diseases which afflict the important crops grown by SSFs. Finally, biotechnology research should strive to solve problems associated with weed infestations, in particular the parasitic weed Striga in maize and sorghum.

The crops to be targeted for biotechnology research, in descending order of importance, were identified as maize, sorghum, pearl millet, finger millet, cotton, tobacco, groundnuts, sunflower, vegetables and tuber crops, cowpeas and other legumes, cassava, wheat and barley. In general food crops were assigned a higher priority than cash crops because food production and security is considered to be of paramount importance to resource-poor farmers. Maize was accorded the highest priority because it is the staple food for the vast majority of the population and is thus the most widely grown crop. Pearl and finger millet were also accorded a high priority due to their drought tolerance and adaptability to more marginal conditions where maize cannot be produced successfully. Of the cash crops, cotton was accorded the highest priority because it is produced by a very large number of SSFs and therefore generates considerable income for these farmers. Although tobacco is the most important cash crop, it was assigned a lower priority than cotton because it is produced predominantly by LSCFs. The lowest priority was assigned to the winter cereals wheat and barley which are produced almost exclusively by LSCFs.

Overall, there is presently little integration of biotechnology within the traditional NARS administered by DR&SS or with priorities in agricultural policies. The only notable example is the integration of tissue culture into the horticultural research programme which is being undertaken with assistance from the World Bank. However, some employees of the NARS are presently undergoing training in biotechnology in overseas institutions and may initiate biotechnology projects subject to the availability of adequate funding. The prospects for further integration of biotechnology into the NARS presently appear bleak due to the lack of financial resources which is already hampering the activities of DR&SS considerably. Furthermore, since it is intended that SIRDC should work closely with DR&SS so as to complement conventional research programmes, it is very likely that support for biotechnology research within DR&SS will not be forthcoming; such support is likely to be channelled to SIRDC instead.

In contrast, biotechnology has been fully integrated into the national tobacco research programme of TRB as a result of a special initiative. This effort has probably been successful due to the single commodity nature of the institution, the higher level of funding available for tobacco research and the concerted campaign undertaken by TRB to promote the potential benefits of biotechnology to the tobacco industry.

Biotechnology Institutions, Organisations and Activities

A number of institutions in Zimbabwe are engaged in biotechnology research and development. They encompass the public and private sectors as well as parastatal organisations. Public-sector institutions include those in the DR&SS, UZ and SIRDC. Relevant institutes in DR&SS include the CRI, LIF and HRC. Although the Crop Breeding Institute of the DR&SS is engaged in the breeding of several crops, it is yet to include biotechnology in its breeding programmes. The TRB is the sole parastatal engaged in biotechnology research while the private sector is represented by the Tissucult company.

Horticultural Research Centre (HRC)

The HRC is an institute of the DR&SS with responsibilities for research in various horticultural crops. Crops under investigation include onions, tomatoes, apples, pears, strawberries, blueberries, peaches, grapes, potatoes and ornamental crops. The centre is in the process of establishing a tissue culture laboratory with the assistance of the World Bank. The primary purpose of the facility is to enable the HRC to handle imported in vitro disease-free germplasm. To date the building and some of the equipment has been acquired but the laboratory is yet to become operational. The laboratory will be managed by a single research officer who has received M.Sc. level training in tissue culture.

Legume Inoculant Factory

The LIF has its origins in the microbiology laboratory of DR&SS which was established at Grasslands Research Station in 1958. The laboratory was initially tasked with the isolation and culture of *Rhizobium* strains suitable for use on a variety of legumes grown in Zimbabwe. Following successful isolation of effective strains and the development of an agar-based culture medium, a special LIF was established in 1962. The factory is now supported technically by a Soil Productivity Research Laboratory (SPRL) which is responsible for maintenance of the *Rhizobium* collection, research and development, supply of mother cultures and quality control. The SPRL possesses an impressive collection of *Rhizobium* strains which number over 700. The relevant activities of the SPRL are overseen by a very experienced technical officer while the LIF is managed by a senior research officer who has received M.Sc. level training in microbiology in the Netherlands.

Most of the inoculant produced is destined for use in soyabean which is an important cash crop grown mainly by LSCFs. However, the factory also produces inoculant for groundnuts, lucerne, field beans and, to a limited extent, peas, sunnhemp, velvet beans, clovers and lupins. Inoculant from the factory is despatched in response to orders and distributed via the Seed Co-op Company and Farmers Co-op stores located throughout the larger towns in the country. Most of the inoculant is used in Zimbabwe although in recent years some has been exported to Ethiopia and Zambia. In addition, small quantities have also been produced for scientists in Cote d'Ivoire, Mozambique and South Africa.

Since its inception, the factory has expanded its production capacity considerably and improved the method of inoculant production and delivery. Present production is about 100 000 units of inoculant although the factory has the capacity to produce as many as 300 000 units. Expansion and upgrading of the facility was financed mainly by the Dutch government and undertaken in anticipation of increased demand from other countries of SADC. However, this demand has failed to materialise because soyabean production in the southern African region has not increased appreciably. Furthermore, other countries such as Zambia have established their own inoculant production facilities. Although the demand for inoculant could be increased considerably if soyabean production and inoculant use were adopted by SSFs, these farmers have shown some reluctance to grow the crop or use inoculant. Further efforts are now being made to promote soyabean production and inoculant use by SSFs with the assistance of the Dutch government Special Programme in Biotechnology. The project will provide for support of research and promotion of domestic use of soyabeans in communal areas rather than offer incentives for SSFs to produce soyabeans.

It is pertinent to note that a special project on groundnut inoculant isolation and culture has also been undertaken by the SPRL. The three-year project was officially launched in December 1989 and intended to benefit mainly communal farmers who are the main producers of groundnuts. Its overall objective was to increase groundnut production by these farmers through the use of appropriate inoculant. The project was financed by the Netherlands government DGIS and executed through a joint agreement between the SPRL and the Vrije Universiteit in Amsterdam. However, it appears that the project was severely hampered by technical and other problems and was therefore abandoned. A socioeconomic study of the project conducted in 1992 concluded that the project was questionable and unlikely to achieve its objectives.

Cotton Research Institute

The CRI is a government-owned organisation which is solely responsible for all research on cotton. Its programmes in breeding, agronomy, physiology, entomology and pathology are geared to meet the needs of both large- and small-scale cotton producers. Although the institute does not have any facilities or personnel to undertake biotechnology research, it nonetheless has ventured into some biotechnology-related research in collaboration with external partners.

In view of the considerable progress that has been made in cotton biotechnology particularly with regard to Bt-induced transgenic resistance to lepidopteran pests, the institute is now engaged in a collaborative research project in this area. The project was arranged by the ISAAA and involves proprietary technology developed by Monsanto. Under this agreement, the CRI will initially test imported Bt protein against local pests under controlled conditions. Thereafter, the tests will be repeated using imported transgenic plants and if successful, will be followed by rapid backcrossing of the transgenic resistance into local cultivars.

To date the initial Bt protein tests have been carried out with some success. However, according to the CRI, control of red bollworm (*Diparopsis castanea*) is problematic and will require further investigations. The project also appears to have been hampered by communication difficulties probably associated with staff changes at ISAAA.

This project represents the first ISAAA-brokered attempt at transferring proprietary biotechnology to Zimbabwe. However, the details of the agreement between the CRI, ISAAA and Monsanto are sketchy. For example, it is not clear what conditions should be met to allow for the commercial use of the technology and how Monsanto will be compensated.

University of Zimbabwe

The Departments of Biological Sciences, Biochemistry, Crop Science and Soil Science at the UZ are engaged in various biotechnology projects as well as the teaching of an M.Sc. course in biotechnology. The M.Sc. biotechnology programme is offered jointly by the Faculties of Agriculture and Science and was initiated in 1991 with assistance from SAREC and the Dutch government. The first 8 students have graduated and 10 have been accepted for the second course. It is anticipated that graduates of the programme will proceed to the D.Phil. or Ph.D. level to better equip them with biotechnology skills and knowledge.

The following are some of the biotechnology projects which are currently in progress at the university:

- molecular marker analysis to characterise the phylogenetic relationships amongst *Tilapia* fish species;

- preliminary studies on Bt genes which could possibly be used for control of mosquitoes and tsetse fly;

- studies on starter cultures for fermentation of milk;

- studies on indigenous *Rhizobium* isolates;

- micropropagation of sweet potato, cassava, strawberries, Irish potato and coffee;

- studies on transformation of cassava, a local *Brassica* spp. popularly known as tsunga, sorghum, sweet potato and tomato;

- studies on the molecular biology of Hepatitis B virus which is responsible for herpatocellular carcinoma; and

- characterisation of Zimbabwean cowpea viruses with the objective of eventually producing transgenic cowpeas with coat protein-mediated protection against virus diseases.

The projects are funded by the UZ and a number of external organisations including DGIS and SAREC. All projects are headed by a Ph.D. level scientist usually with assistance from locally trained technicians.

Scientific and Industrial Research Development Centre

The SIRDC represents a new and exciting development in the quest for science and technology driven development in Zimbabwe. Establishment of the centre was proposed in 1989 and construction of facilities is now underway. When complete, the centre will consist of the five following institutes: Biotechnology, Building Engineering, Microelectronics, Energy and Mechanical Engineering.

The objectives of the Biotechnology Institute are:

- to undertake research into applied animal and plant genetics with a view to producing species that are adaptable to the varied Zimbabwe environment;

- to develop crop varieties suited to growth in marginal areas of Zimbabwe, including those crops that will be of benefit to small-scale farmers;

- to develop expertise and provide services in food processing to enable community enterprises and the food industry to improve Zimbabwean agricultural commodities;

- to develop diagnostic tools and vaccines for animal and human health;

- to provide technical expertise in collecting germplasm of endangered species as well as in establishing and maintaining a gene bank;

- to take the initiative in adapting biotechnology to local needs and applications; and

- to contribute to national and international legal procedures on issues related to biosafety and intellectual property rights.

SIRDC has sought technical assistance from the Dutch Government in the planning of the Biotechnology Institute. A proposal for establishment of the institute has been prepared by Dutch experts and is being considered. The centre has also launched a staff development programme to ensure that highly trained personnel are engaged to carry out its mandate. Suitable candidates are being identified and will be offered staff development scholarships to enable them to train in overseas institutions.

Although the Biotechnology Institute is still in its formative stages, SIRDC has already launched an initiative to identify suitable biotechnology projects for implementation in the near future. As such, it is presently deliberating over proposals for a micropropagation project which will provide planting material to resource-poor farmers. Crops under consideration include cassava, sweet potato, Irish potato and possibly strawberry. It is intended that the project will initially focus on cassava and sweet potato and thereafter be expanded to include the other crops.

Tobacco Research Board

Biotechnology research at TRB has been carried out for several years but only recently has the Board decided to establish a biotechnology department. Prior to this, biotechnology research, primarily in tissue culture, was undertaken by the department of Plant Breeding. As a result of its work in anther culture, the department released the first ever doubled haploid cultivar which is still grown today. The department has also carried out tissue culture studies in an attempt to overcome interspecific incompatibility barriers.

The Biotechnology department was formed in 1991 and officially opened in 1994. Extensive infrastructure development costing over Z$ 2.6 million has been completed and approximately Z$ 1.3 million will be spent on equipment. Greenhouse facilities for contained testing of transgenic plants are budgeted at Z$ 200 000. The development of this department represents perhaps the most ambitious venture into plant biotechnology research and development in Zimbabwe. When complete, the department will be well equipped and staffed to undertake a wide range of biotechnology research activities for the tobacco industry. Staff in the department presently consist of two Ph.D. level biotechnologists, a B.Sc. level research officer and a locally trained technician.

The general objective of the Department is to develop a variety of new and novel techniques for the genetic improvement of tobacco. Its long-term objectives are to provide material for the Plant Breeding Department and transform prescribed cultivars with useful genes for disease and pest resistance. The following projects are in progress:

- protoplast fusion and production of asymmetric hybrids for the rapid development of male-sterile lines;

- establishment and evaluation of in vitro nodal propagation systems for production of clonal planting material;

- investigations on leaf disc transformation and regeneration designed to develop a routine system for development of transgenic plants. Studies include response of regeneration to cytokinin concentration, and sensitivity of caulogenesis and callogenesis to kanamycin concentration;

- agrobacterium-mediated transformation of prescribed cultivars with neomycin phosphotransferase and beta-glucuronidase;

- contained evaluation of transgenic lines for resistance to the bacterial diseases wildfire and angular leaf spot. The lines carry a bacterial tabtoxin-acetyltransferase self-protection gene;

- transformation of prescribed cultivars with tabtoxin-acetyltransferase for development of cultivars with resistance to bacterial diseases and field testing of such lines for disease resistance, yield and quality;

- basic studies on the molecular basis of rootknot nematode (*Meloidogyne javanica*) resistance by protein characterisation;

- production of transgenic plants carrying chitinase gene constructs and evaluation of such lines for resistance to fungal diseases; and

- development of an in vitro selection system for resistance to Alternaria blight (*Alternaria alternata*).

In addition to the above projects, negotiations for testing other potentially useful genes that might confer resistance to disease and pests are in progress. The department collaborates closely with academic institutions in South Africa, the University of North Carolina, Monsanto and a few research institutions in Japan.

It is particularly relevant to note that the TRB has already carried out some contained testing of transgenic plants and also proposes to undertake field evaluation as soon as its application is approved. The TRB application is being evaluated in collaboration with Dutch experts and it is proposed that this case be used as a training exercise in biosafety evaluation and oversight. Evaluation of the TRB proposal is however being hampered by delays in the formalisation of biosafety mechanisms.

Tissucult

Tissucult is a privately owned plant micropropagation company established to produce high-yielding and ostensibly disease-free foundation planting material for the horticultural industry. The company possesses a modest tissue culture facility which is managed by an externally trained technical expert and two assistants who were trained internally. Its main clients are LSCFs and private corporations.

The company is, or has been active in the propagation of bananas, strawberries, carnations, chrysanthemums, coffee, raspberry, potatoes, hops, asparagus, orchids, leather leaf fern and asters. Experimental projects in progress include propagation studies on Alstroemeria, jatropha, cucumber, blueberry and ornamentals. Although a major objective of the company is to produce disease-free planting material, it cannot guarantee disease elimination due to the lack of adequate pathogen detection facilities such as ELISA.

The main constraint to pathogen testing is the high cost of anti-sera which has to be imported. As a result, virus indexing has to undertaken by externally based institutions.

Biotechnology Forum of Zimbabwe

The Biotechnology Forum of Zimbabwe (BFZ) was formed in 1992 and is comprised of representatives from DR&SS, AGRITEX, the UZ, SIRDC, the African Centre for Fertiliser Development (ACFD), the ZFU which represents the interests of SSFs only, and the non-governmental organisations ENDA, ORAP, COOPIBO, COMMUTECH and Silveira House. In view of its orientation toward the interests of SSFs only, it does not have a representative from the CFU.

The idea of the Forum was initially perceived and supported by ENDA which then sought representatives to the Forum from various institutions and organisations with interests in small-scale agriculture and biotechnology. However, after its formation and formulation of a biotechnology strategy for SSFs, the Forum attracted the interest of DGIS which subsequently provided funding for its activities with the intention that the Forum would provide advisory services to DGIS for its Special Programme in Biotechnology. Until recently, the Secretariat of the Forum was housed by ENDA with the activities of the Forum being overseen by a co-ordinator seconded to the NGO.

The original purpose of the Forum was to stimulate, organise and co-ordinate biotechnology activities which are relevant to resource-poor farmers. As such, it was intended to serve as a forum for interaction between scientists, farmers, policy makers, rural development organisations, NGOs and extension workers. In its 1992 proposal, the Forum proposed to formulate a coherent strategy on biotechnology for resource-poor SSFs within the context of the social, cultural and political environment in the country. In pursuance of the objectives of the Forum and with the support from DGIS, the following studies have been carried:

- Inventory of Biotechnology Activities in Zimbabwe;

- Biotechnology for Resource-Poor Farmers: Crop Production Constraints, Institutional Biotechnology Capabilities and Priorities; and

- A Background and Socio-economic Study on Soyabean Production in the Communal Areas of Zimbabwe with Particular Reference to Biotechnology Intervention.

- A socio-economic study on cassava production and biotechnology intervention is in progress.

Since its inception, the Forum has undergone changes. In the contract with DGIS, it is proposed that the Forum have two functions. The first will be to promote the application of biotechnology in crops, animals and forestry, with special emphasis on seeking sustainable solutions to the production constraints facing resource-poor SSFs. The second will be to act as an advisory body to the Dutch government Special Programme in Biotechnology so as to assist it in identifying areas of co-operation in crop biotechnology. As such, the Forum has an important role to play in the formulation and implementation of the biotechnology research programme which is targeted towards the needs of the numerous SSFs of Zimbabwe.

Private-Public Sector Co-operation and Partnerships

The prevailing model of biotechnology research in Zimbabwe differs considerably from that in developed countries where a considerable amount of the research is being conducted by the private sector. In contrast, most of the biotechnology research in Zimbabwe is being carried out by public-sector institutions and parastatals. Except for a single commercial micropropagation facility, little or no biotechnology research is being undertaken in the private sector. Furthermore, it appears that the future development of biotechnology will be based largely on public sector research with only limited private sector involvement in product development in instances where there is effective demand for biotechnology products. In view of the limited support for biotechnology research in the private sector, very few public-private-sector partnerships have been established. The only notable example involved a short-term agreement between Delta Corporation and the UZ for the development of micropropagation techniques for hops.

An interesting example of parastatal-private sector collaboration in the development of a biotechnology-related product is provided by the recent commercialisation of a myco-fungicide by the agrochemical company Agricura. Development of the product is based on research carried out by the TRB which demonstrated that application of the fungus *Trichoderma harzianum* to seedbeds provides some control of damping off (*Rhizoctonia* spp.) as well as a growth stimulating effect to seedlings. Following this discovery and the conclusion of an agreement between TRB and Agricura, the latter undertook product development studies which have culminated in the development of a suitable delivery and application system based on culture of the fungus on wheat chaff. Under the agreement, the TRB receives undisclosed financial compensation from the agro-chemical company. Agricura is presently producing about 120 tonnes per year of the *Trichoderma*/wheat chaff inoculant mainly for use in tobacco seedbeds and horticulture. Demand for the myco-fungicide is considerable and present production represents only about 20 per cent of the total demand. It is envisaged that production will gradually be scaled up to meet national demand.

The emphasis of agricultural biotechnology research on the needs of SSFs has considerable implications for public-private sector partnerships in research and technology development. Given that the interests of SSFs are best served by the public sector, and because SSFs attract little interest from the private sector, it is highly unlikely that such partnerships will be established. Instead, biotechnology research targeted for SSFs is likely to remain in the public sector domain.

External Partners in Biotechnology

In view of the relatively sophisticated and advanced nature of the agricultural sector in Zimbabwe, the country has attracted considerable attention from external organisations involved in biotechnology research, applications and technology transfer. These include the International Service for the Acquisition of Agri-Biotech Applications (ISAAA) and the Special Programme in Biotechnology of the Dutch Government Directorate General for International Co-operation (DGIS). However, Zimbabwe is yet to be included in the Agricultural Biotechnology for Sustainable Productivity (ABSP) initiative.

International Service for the Acquisition of Agri-Biotech Applications (ISAAA)

The ISAAA is a non-profit international organisation whose aim is to facilitate the acquisition and transfer of agricultural biotechnology applications from the industrialised countries, particularly proprietary technology from the private sector, for the benefit of developing countries. The organisation has carried out exploratory forays into Zimbabwe and is presently involved in two projects, one of which is already in progress. The first and most advanced project is on Bt-induced transgenic resistance to lepidopteran and other pests in cotton. This project is being undertaken by the CRI in collaboration with ISAAA and Monsanto. The second project entails the micropropagation of introduced fruit trees and will be carried out by the HRC of DR&SS. The project is presently awaiting implementation pending approval of funding by the German agency GTZ.

DGIS Special Programme in Biotechnology

The Dutch Government Special Programme in Biotechnology and Development Co-operation has been active in Zimbabwe since 1992 and is the most important external partner in biotechnology development. The programme was established by the Dutch government in January 1992 and is effected through DGIS. It is intended to run for 5 years and has been allocated a budget of US$6 million.

The objectives of the programme are to:

- improve the access of developing countries to biotechnological expertise and innovations and thereby contribute to the solution of development problems;

- integrate the development perspective within the Dutch biotechnology programmes so as to prevent possible negative consequences in developing countries. Of particular concern are substitution of export commodities by biotechnology based products in developed countries and field testing of transgenic material in developing countries;

- co-ordinate activities in biosafety and intellectual property rights in targeted countries;

- provide technical co-operation in biotechnology to Zimbabwe, Colombia, Kenya and in Karnataka State in India. Such assistance must be based on proper needs assessment and may consist of capacity building and/or technical projects.

The programme focuses on development constraints in agriculture, health care and environmental protection and its sole target group are resource-poor SSFs. Its activities are primarily founded on needs assessment and priority setting based on a problem-oriented "interactive bottom-up" approach rather than technology push. As such, the programme insists on close consultation with the beneficiaries in the assessment of needs, priority setting, and project formulation and implementation.

To date the Programme has provided financial support for the following activities and projects:

- administration of the affairs of the BFZ;

- upgrading of the LIF facilities and provision of training to its manager;

- cassava biotechnology research at UZ;

- M.Sc. Biotechnology training at UZ;

- a priority setting exercise for small-scale farmers;
- socio-economic studies on biotechnology intervention in soyabeans and cassava; and
- a regional conference on international co-operation on safety in biotechnology.

The Programme has greatly assisted the development of biotechnology in Zimbabwe and continues to provide invaluable support.

Other External Partners

A number of other institutions have also contributed to the development of biotechnology in Zimbabwe. They include a pharmaceutical research centre in Japan which has provided the TRB with technology for the production of transgenic plants with bacterial self-protection resistance to the bacterial wildfire disease. The initiative for this project was initially launched by the co-operating Japanese partner which was primarily interested in field-testing of transgenic lines developed in Japan. However, following appraisal of the project by TRB and the conclusion of an agreement, a technology package which will enable local production of transgenic lines was made available to TRB. This collaborative project has culminated in the first application for field testing of a transgenic plant.

The IARCs offer considerable prospects for technology transfer and development for important food crops such as maize, wheat, sorghum, millet, potato, sweet potato, millet and beans given that their research programmes could provide relatively easy and uncostly access to biotechnology innovations. However, opportunities for technology transfer from these institutions are yet to materialise. If and when such opportunities do arise, it is highly likely that they will be actively pursued given Zimbabwe's long-standing and good relationship with several IARCs.

Biosafety

Zimbabwe has taken a leading role within Africa in addressing biosafety but has yet to finalise its position on this matter. The initial initiative to address biosafety was taken by the RCZ when it requested a three-person task force to draft Biosafety Guidelines. A "Proposal for Recombinant DNA Biosafety Guidelines" was subsequently prepared after reviewing those from countries such as The Netherlands, USA, Australia, India, EC countries, Latin America as well as the views of local scientists and members of the public from interested sectors of the economy. The proposal was vigorously discussed and debated at two one-day workshops held in Harare in 1991 and 1992 with the central issue being whether the regulation of biotechnology should be based on voluntary guidelines legislation. The consensus at both workshops was that the guidelines should be legislated so as to enhance accountability and effectiveness.

A revised form of the guidelines has since been prepared and presented to the RCZ but little progress has yet been made in resolution of the issue. Indications are that the RCZ is in a dilemma as to whether the guidelines should be based on a voluntary code of conduct or legislated by government. While legislation is preferred to ensure compliance, it is feared that this approach may stifle the development of biotechnology in the country. On the other hand, lack of legislation may result in risky studies being undertaken. A further dilemma is that the proposed Biotechnology Safety Board which will have oversight on biotechnology research can only be set up through legislation. Clearly, the finalisation of the biosafety issue is faced with difficult hurdles which must quickly be overcome if biotechnology research is to advance in Zimbabwe.

Intellectual Property Rights

Although Zimbabwe has a Patent Act and is party to the Paris Convention for Protection of Industrial Property, it does not have an intellectual property rights system for biotechnology. While it is acknowledged that the absence of such a system will hinder the country's ability to acquire proprietary technologies from developed countries, as yet no effort has been made to develop a system which is conducive to the acquisition of such technologies. The prevailing approach to acquisition of biotechnology related technologies is thus based on special arrangements between local researchers and external partners, and some negotiated arrangements brokered by the ISAAA.

Zimbabwe is a member of the African Regional Industrial Property Organisation (ARIPO) an intergovernmental organisation which was formed in 1976. One of its objectives is to assist its members in the acquisition and development of technology relating to industrial property. However, the organisation is yet to play any role in assisting its member states to acquire proprietary biotechnology from industrialised countries.

V. BIOTECHNOLOGY AND SUSTAINABLE CROP PRODUCTION

According to the Technical Advisory Committee of the CGIAR, sustainable agricultural systems "should involve the successful management of resources for agriculture to satisfy the changing human needs while maintaining or enhancing the quality of the environment and conserving natural resources". Reduction in the use of pesticides through biotechnology intervention could be a significant contribution to sustainable agricultural systems which is less harmful to the agricultural production base and the environment in general.

Opportunities for Biotechnology Intervention in Crop Production

The potential for biotechnology to contribute to more sustainable crop production and protection is dependent on the following:

- the relative importance of the crop and the prevailing system of its production. As such, opportunities for the contribution of biotechnology to more sustainable production will be greatest for those crops which are produced by LSCFs under high-input conditions. The least opportunities in this regard will apply to minor crops which are grown under low input conditions largely by SSFs and CAFs;

- the nature of the biological constraints to production;

- the extent to which agrochemicals are used in production of the crop;

- the extent, success and prospects for control of the major biological constraints by alternative non-chemical methods such as breeding for resistance or tolerance;

- the state-of-the art in biotechnology for the particular crop.

As such, the prospects for biotechnology intervention are greatest for important crops in which considerable progress in biotechnology research has been made, and for the amelioration of biological constraints which can only be controlled by the application of agrochemicals.

Maize

The main diseases of maize include ear rots caused by *Diplodia* spp. and *Fusarium* spp., leaf blight (*Helminthosporium turcicum*) and streak caused by maize streak virus. Losses attributable to ear rots and leaf blight are unknown but can be as high as 30 per cent for maize streak virus which is transmitted by a leafhopper. The most important insect pest is the maize stalk borer (*Buseola fusca*) which is particularly prevalent in late planted crops and, if not controlled, can result in considerable yield losses as high as 50 per cent. Leaf hoppers are important as vectors of maize streak virus. Other pests such as the African armyworm (*Spodoptera exempta*) and termites occasionally cause some damage particularly in the small-scale subsector.

Conventional control of maize pests and diseases is restricted to breeding for resistance or tolerance and application of agrochemicals. Plant breeding has been particularly successful in the development of hybrids with resistance to ear rots and leaf blight. More recently, some success in the development of hybrids with resistance to maize streak virus has also been achieved by Seed Co-op. However, breeding for resistance to stalk borer has not been pursued due to the absence of sources of resistance. As a result, this pest can only be controlled by chemical means.

Potential applications of biotechnology in maize production thus consist of the development of transgenic lines and hybrids with resistance to stalk borer and perhaps streak virus. The most notable opportunity is in the development of material with transgenic resistance to stalk borer given that the use of conventional breeding techniques has already resulted in the production of hybrids with some resistance to streak virus. In view of the success that has already been achieved in the development and testing of transgenic maize with Bt-induced resistance to stalk borer, there is considerable potential for the application of this technology in Zimbabwe.

Tobacco

The important pests and diseases in tobacco include the following:

- rootknot nematode (*Meloidogyne javanica*) which is very widespread and requires that virtually all tobacco lands be fumigated with ethylene dibromide. In addition, rotation of tobacco crops with leys of nematode-resistant grasses or other crops is routinely practised to reduce nematode populations;

- Alternaria leaf spot (*Alternaria alternata*) which can be a problem in susceptible cultivars;

- wildfire (*Pseudomonas syringae* pv. *syringae*) and the related angular leaf spot (*P. syringae* pv. *angulata*);

- powdery mildew (*Erysiphe cichoracearum*) which, like alternaria leaf spot can be serious in susceptible cultivars; and

- tobacco mosaic virus (TMV) and bushy top virus. TMV can be serious in susceptible cultivars while bushy top occurs sporadically and is not of major concern.

Conventional breeding for resistance to most of the important bacterial, fungal and viral diseases has been successful such that most tobacco cultivars have some resistance to alternaria leaf spot, wildfire, angular leaf spot, powdery mildew and TMV. Considerable progress has also been made in the development of hybrids with some resistance to rootknot nematode. However, little success has been achieved in breeding for resistance or tolerance to bushy top virus and no effort has been made to breed for resistance or tolerance to budworm and the other less important insect pests. Control of budworm and other insect pest is thus entirely dependent on the application of pesticides.

Potential applications of biotechnology in tobacco production include:

- the use of Bt-transgenic lines for control of budworm and other lepidopteran pests;

- coat protein mediated protection for control of bushy top virus; and

- control of wildfire and possibly angular leaf spot using transgenic lines with a bacterial self-protection gene.

The control of budworm offers the best opportunity for the application of biotechnology because wildfire and angular leaf spot can be controlled by conventional breeding while bushy top is not of sufficient importance to warrant biotechnological intervention.

Cotton

The important biological constraints to cotton production are:

- bollworms including Heliothis bollworm (*Helicoverpa armigera*), red bollworm (*Diparopsis castanea*), pink bollworm (*Pectinophora gossypiella*) and spiny bollworm (*Earias* spp.). These pests pose the most serious threat to cotton production and can cause considerable losses if not controlled;

- aphids and white fly (*Bemisia tabaci*);

- red spider mite (*Tetranychus urticae*);

- jassids (*Empoasca* spp.);

- Verticillium wilt (*Verticillium dahliae*); and

- bacterial blight (*Xanthomonas campestris* pv. *malvacearum*).

Control of jassids and bacterial blight has been adequately achieved by conventional breeding while limited progress has been made in breeding for resistance to Verticillium wilt. In contrast, control of bollworms, aphids, whitefly and red spider mite is limited to the application of pesticides. Widespread occurrence of these pests requires that cotton crops be rigorously scouted and that the appropriate pesticides be applied in accordance with established recommendations.

In view of the economic importance of cotton, the nature of its important pests and the advances that have been made in biotechnology particularly as regards the development of Bt-based transgenic lines, the prospects for the application of biotechnology are greatest in this crop. The most appropriate and promising application of biotechnology is in the use of Bt-transgenic lines for the control of lepidopteran pests which presently can only be controlled by chemical means. If successful, widespread adoption of transgenic varieties which confer adequate protection against lepidopteran pests could result in a considerable reduction in the use of pesticides by both LSCFs and SSFs.

Soyabeans

Soyabeans are an important crop in the large-scale commercial-farming subsector and offer considerable prospects for improvement of the income and nutrition of SSFs and CAFs. However, widespread adoption of this crop by SSFs and CAFs will require a more concerted promotion and extension programme. The important biological constraints to soyabean production are:

- little or no use of *Rhizobium* inoculant by SSFs and CAFs;

- diseases such as bacterial blight *(Pseudomonas syringae* pv. *glycinea*) and red leaf blotch (*Pyrenochaeta glycines*). The latter poses the most serious threat and can reduce yields by as much as 50 per cent; and

- Insect pests, in particular various looper caterpillars.

The development of appropriate *Rhizobium* inoculants for soyabean has been very successful in Zimbabwe and their use is commonplace among LSCFs. Despite some attempts to promote and encourage inoculant use by SSFs and CAFs, little progress has been made in the use of this inexpensive technology in these subsectors. There is limited interest in the production of soyabeans by these farmers, therefore increased awareness and use of this technology is likely to be accomplished only if the crop is successfully promoted and adopted by SSFs and CAFs.

Control of the important soyabean diseases is accomplished by sanitation and chemical application only, due to the limited progress in breeding for disease resistance. At present, the state-of-the-art in soyabean biotechnology appears to offer limited prospects for application of alternative methods of disease control which could contribute to reduced pesticide usage.

The control of various semi-looper caterpillars by the application of nuclear polyhedrosis virus represents an outstanding example of the application of biological control for an important insect pest. However, because this method of control is effective against only a limited number of insect pests, it could perhaps be supplemented by the use of cultivars with Bt-based transgenic resistance. If successful, such a system would represent a good example of the integration of biotechnology with biological control.

Sorghum and Millets

The important biological constraints to sorghum production are:

- the diseases smut (*Sporisorium sorghi* and *S. reiliana*), leaf blight (*Exserohitum sorghi*), ergot (*Sphacelia sorghi*) and downy mildew (*Perenoscleropspora sorghi*); and

- insect pests such as spotted stemborer (*Chilo petreullis*) and shootfly (*Atherigona soccata*). The former can cause yield losses of up to 50 per cent depending on the level of infestation.

The control of ergot and smut is easily effected by the application of seed dressings whereas breeding for resistance is possible for the control of leaf blight and downy mildew. In contrast, very limited progress has been made in breeding for resistance to the important insect pests. In view of the developments in sorghum biotechnology, there are considerable prospects for the control of stemborer by the use of Bt-based transgenic varieties.

Important biological constraints to pearl millet production include ergot (*Claviceps fusiformis*) which can cause yield losses of up to 100 per cent and smut (*Tolyposporium penicillaria*). There are no serious pests except nematodes which can adversely affect performance in over cropped soils. Although host resistance to ergot and smut is available, it is mostly partial and not very effective against these diseases.

Although there are prospects for the application of biotechnology in sorghum and pearl millet production, it appears that such intervention offers limited prospects for the adoption of more sustainable production systems in the context of reduced pesticide usage. However, such intervention could still provide for more sustainable production through the reduction of insect pest damage.

Other Crops

Fairly substantial quantities of fungicides are used for the control of coffee leaf rust (*Hemilia vastatrix*) and bark disease (*Fusarium stilboides*) due to the limited success in breeding for resistance to these diseases. Little or no pesticides are applied. Although the coffee crop is produced mainly by LSCFs, the state-of-the-art in coffee biotechnology appears to offer little or no prospects for the introduction of biotechnology-related technologies which could contribute to implementation of more sustainable systems of production. However, the development of cultivars with resistance or tolerance to the important fungal diseases could make a significant contribution to sustainable coffee production.

The important constraints to groundnut production include early leaf spot (*Cercospora arachidicola*), web blotch (*Phoma arachidicola*), grey mould (*Botrytis cinerea*), late leaf spot (*Cercosporidium personatum*), groundnut rosette virus and leafhopper. Control of diseases is restricted to breeding for resistance and sources of partial resistance have been identified and are being used in the local breeding programme. Biotechnology intervention, particularly in the form of coat protein-mediated protection against rosette virus could possibly be used in groundnut production.

Potato production is constrained mainly by late blight (*Phytopthora infestans*), bacterial blight (*Pseudomonas* spp.), various viruses (e.g. mosaic, leaf roll and potato viruses X and Y) and tuber moth (*Phthorimea operculela*). While some success has been achieved in breeding for partial resistance to late blight, considerable quantities of agrochemicals are still used by LSCFs for the control of late blight and tuber moth. Therefore, biotechnological intervention, particularly in the form of transgenic varieties with resistance to late blight and tuber moth could contribute to more sustainable production systems.

The important biological constraints to sugarcane production include smut (*Ustilago scitaminea*), leaf scald (*Xanthomonas albilineans*) and ratoon stunting disease (*Clavibacter xyli* subsp. *xyli*). Smut is the main disease and is controlled by conventional resistance breeding and strict sanitation while ratoon stunting disease is controlled by heat treatment of planting material. As such, agrochemicals are used to only a very limited extent in sugarcane production. Therefore, there are limited opportunities for the application of biotechnology-related technologies which could contribute to more sustainable systems of sugarcane production.

For the minor crops such as sunflower, cowpea, castor and sweet potato which are grown mainly by CAFs and SSFs, there are very limited opportunities for biotechnological intervention which could result in more sustainable production systems based on reduced agrochemical usage. Although there are prospects for the application of biotechnology in some of these crops, such intervention will have very limited impact on pesticide use because little or no pesticides are presently used in the production of these crops. Nonetheless, biotechnological intervention in these crops could still make a significant contribution to sustainable production by reducing the impact of important diseases and pests.

Incentives for Biotechnological Intervention in Crop Production

The incentives for reduced pesticide usage which have been alluded to earlier indirectly impinge on the application of biotechnology in crop production. Of greatest significance is the economic incentive which is associated with the tremendous increase in the price of imported agrochemicals. However, the increase in agrochemical costs will only act as real incentive for the application of biotechnology-related solutions if their cost is less than that of the required chemicals. In addition, it is important that biotechnological solutions provide a level of protection against pests and diseases which is equivalent to that achieved through the use of agrochemicals.

Although there is clearly an environmental incentive for the adoption of biotechnology in high input crop production, it appears that this incentive is yet to be important in Zimbabwe. Despite some awareness of environmental issues in the country, it seems that such concerns are yet to result in a concerted effort to reduce agrochemical use. In the absence of such widespread awareness and clearly demonstrated cases of environmental pollution associated with agrochemical use, there is presently little or no incentive for farmers to adopt biotechnology-related production systems which would reduce agrochemical use. However, difficulties in chemical pest control associated with the development of insect resistance, the intensive use of synthetic pyrethroids, and the adverse effect of pesticide residues on the marketability of agricultural products, have demonstrated the limitations and risks of pesticide use. They could therefore serve as effective incentives for the adoption of biotechnology related technologies.

Constraints to Biotechnology Research, Technology Development and diffusion

While it is evident that there are real prospects for the application of biotechnology innovations which could result in more sustainable production of a number of crops, it is important to note that biotechnology research, and technology development and diffusion in Zimbabwe are constrained by several factors. The main constraints to biotechnology research are:

- Lack of adequately trained scientists who can formulate and pursue relevant biotechnology research projects. The most acute need is for experienced Ph.D. level scientists who have preferably undergone postdoctoral level training in overseas institutions;

- Lack of technical support staff specifically trained in biotechnology techniques and applications;

- Inadequate financial resources for effective biotechnology research. Most of the institutions which have opted to pursue biotechnology research projects continue to be hampered by lack of funds for the purchase and maintenance of essential equipment and running costs. This constraint will likely hinder the full development of the Biotechnology Institute of SIRDC as well; and

- Lack of a definitive policy on biosafety and the conduct of biotechnology research in the country. This situation has hampered some research projects of TRB and, unless resolved in the near future, will retard progress in other projects.

Technology development in biotechnology is likely to be constrained by:

- Lack of technology development expertise and experience within research institutions engaged in biotechnology research;

- Lack of technology development agencies which are able to utilise research findings and readily transform them into technologies which can be easily made available to client groups; and

- Poor communication and linkages between research and technology development agencies. Distrust of the intentions of potential technology development agencies by researchers is also likely to hinder progress.

The major constraints to technology diffusion are:

- Inadequate manpower for widespread and effective contact with clients who are widely scattered throughout the country;

- Inadequate knowledge of extension workers as regards the use of biotechnology products for the improvement of crop production;

- Lack of adequate financial resources for technology diffusion programmes. Inadequate funding of the extension service, particularly under conditions of economic structural adjustment, continues to severely hinder its ability to deliver adequate services to a large client group;

- Unavailability of financial resources to enable farmers to adopt new and improved technologies. This problem is particularly acute among SSFs who do not have easy access to credit facilities;

- Inadequate development of technology packages which can serve as a ready and effective vehicle for the transfer of biotechnology innovations to farmers. Of particular relevance in this regard are the problems experienced in the production and distribution of seed of crops which are mainly grown by SSFs;

- The high cost and inappropriate delivery of technology packages associated with the diffusion of biotechnology innovations. For example, the high cost and inappropriate packaging of improved seed of some crops has discouraged SSFs from adopting improved cultivars;

- Lack of robust and appropriate technologies which can be easily adopted by most farmers. For example, inoculation of soyabean seed by SSFs has proved problematic because the inoculant technology is demanding in terms of its requirements for cold storage and handling;

- Farmer conservatism and the tendency for SSFs in particular to be risk averse; and

- The level of sophistication of the targeted farming group and its willingness to participate in innovative technologies. While the large-scale commercial farming subsector is likely to adopt new innovations which offer the prospects for more profitable crop production more readily, technology diffusion and adoption among the less sophisticated and risk averse SSFs will likely be slower.

Comparative Cost-Effectiveness of Biotechnology Intervention

To date only very limited commercial application of biotechnology innovations has occurred in Zimbabwe. As a result, very little or no information is available to allow for comparison of the cost-effectiveness of biotechnology products with agricultural technology produced by conventional means. Although tissue culture techniques are being used for commercial production of planting material of some crops, no economic data is available on these endeavours.

The studies undertaken on the use of fertiliser and inoculants in soyabeans grown in communal areas provide the only information on the effectiveness of a biotechnology intervention on an experimental scale. These studies indicate that in seasons with adequate rainfall, the application of inoculant alone can increase yields by 10-275 per cent depending on inherent soil fertility, particularly as regards nitrogen level. Overall, these studies have demonstrated that inoculation may, on average, improve the soyabean yields of CAFs be approximately 125 per cent. In some instances, inoculation alone has produced yields which are similar to those of well fertilised plots although it is generally recommended that some fertiliser should be used in combination with inoculant. Given that inoculant costs substantially less than fertilisers, some of these studies thus indicate that in certain instances, the use of inoculant is considerably more cost-effective than fertiliser application.

VI. CONCLUSIONS AND POLICY IMPLICATIONS

The principal objective of this study has been to assess whether the application of biotechnology in Zimbabwe is likely to contribute to more sustainable systems of crop production which are based less on the use of agro-chemicals. To this end, background information on the agricultural sector and the prevailing macroeconomic environment was firstly compiled, followed by analysis of the following: the status of crop research particularly as regards plant breeding and seed production; the status of technology transfer mechanisms for different farming groups; pesticide use in different farming groups and its relevance to sustainable crop production; the incentives for reduced pesticide usage and adoption of biotechnology innovations; programmes and priorities in biotechnology research; the major constraints to crop production and the opportunities they are likely to provide for biotechnology intervention; the major constraints to biotechnology research, technology development and diffusion. Limited commercial application of biotechnology precluded a thorough analysis of the cost-effectiveness of biotechnology interventions relative to conventional methods.

It is clear that, in general, Zimbabwe possesses a fairly sophisticated and well developed agricultural sector which is ready for the application of biotechnological interventions in crop production. However, any considerations should bear in mind the heterogeneity of the sector, in particular the dichotomy between the economically dominant and more sophisticated LSCFs, and the numerically dominant and more marginalised CAFs. The vast differences between these subsectors in farming systems, access to financial resources and technology, innovativeness, and technology adoption and diffusion will undoubtedly bear heavily on the suitability, need and prospects for biotechnological intervention in crop production. As a result, one of the major policy decisions to be confronted is the role of biotechnology in these two main subsectors particularly with respect to more sustainable crop production. In this regard, it will be particularly important to delineate the needs and priorities of LSCFs and CAFs and thereafter formulate clear policy guidelines as to the role of biotechnology intervention in the two subsectors.

The situation of the disadvantaged CAFs undoubtedly requires the greatest attention given that these farmers will be least able to adopt biotechnological innovations. In this regard there is clearly a need for policy measures which will enhance the prospects for adoption of useful biotechnology innovations by CAFs. The most obvious policy measure which requires serious consideration is providing incentives to introduce biotechnologically based products such as transgenic seeds. In the past, the government subsidised fertiliser application. While this approach will likely prove difficult due to the prevailing environment of economic structural adjustment, it is nonetheless a policy option which could facilitate the adoption of biotechnological innovations by the CAFs.

It is also evident that Zimbabwe possesses a well developed system of agricultural research which encompasses the public, private and parastatal sectors, NGOs and IARCs as well as fairly extensive contact with external organisations and institutions with interests in biotechnology research and applications. The research system provides a good foundation upon which complementary biotechnology research can be pursued to supplement the gains made using conventional techniques, particularly for plant breeding. However, there is a need for clear policy guidelines on either the integration of biotechnology research into the NARS or linkages between the Biotechnology Institute of SIRDC and the NARS. If SIRDC is to become the sole government agency responsible for biotechnology research, it is essential that its working relationship with DR&SS be clarified to ensure that the two institutions co-operate fully and to the best advantage of crop research. The need for full co-operation is particularly acute given that there are limited and declining financial resources available for research. Furthermore, it is essential that the policy guidelines address the issue of balance between conventional and biotechnology research so as to ensure that conventional research continues to generate advances in agricultural technology and thereby maintains a solid foundation for the application of biotechnology innovations.

Although agricultural research in general is well organised and productive, it should be noted that any endeavours in biotechnology research are presently constrained by several factors which have been discussed in this study. Therefore, it should be recognised that the local research effort will require considerable external support if it is to meet its objectives. Among the policy issues that require consideration are the extent to which technology transfer from developed countries should be pursued relative to development of local capacity in biotechnology research.

It is evident that Zimbabwe possesses a fairly well developed system for transferring agricultural technology to both LSCFs and CAFs. However, it should be noted that transfer of biotechnology related technologies to LSCFs may be hampered by conflict of interest in the large agro-chemical companies which provide most of the technological guidance to these farmers. On the other hand, transfer of biotechnological innovations to SSFs and CAFs will be dependent almost entirely on the national extension service and NGOs. As such, technology transfer to these farmers is likely to be hampered by inadequate extension services. Furthermore, inadequate production and distribution of seeds of crops which are mainly grown by these farmers will also likely adversely affect the transfer and diffusion of biotechnology innovations. Past experience indicates that there is need for policy initiatives to address the issue of seed supply to CAFs. Among the policy options are the provision of government incentives to encourage seed associations to produce and distribute seed of crops which are important to CAFs. Alternatively, a more concerted effort could be made to produce such seed on state-owned farming enterprises.

The prospects for adoption of biotechnology innovations will be strongly influenced by the nature of the agricultural production base. Accordingly, adoption rates by LSCFs and SSFs are likely to differ considerably. In the large-scale commercial farming subsector, which is more sophisticated and profit-oriented than the other subsectors, adoption will be determined largely by financial considerations. Therefore, if there are economic benefits associated with the application of biotechnology innovations in view of the prevailing economic situation. In contrast, adoption of biotechnology innovations by SSFs will face considerable hurdles and therefore require special attention. It is particularly important to note that the adoption of biotechnology innovations by both LSCFs and CAFs is likely to be minimal if their considerations are environmental alone; other more attractive and tangible incentives, such as pest or disease resistance or increased yields will be required.

The survey of the major biological constraints to crop production and consideration of the success that has been achieved in their control by non-chemical and chemical means indicates that there are real opportunities for biotechnology intervention which could lead to reduced pesticide usage. However, these opportunities are restricted to important crops such as maize, tobacco and cotton. Very limited or no meaningful opportunities exist for crops which are produced largely by SSFs and CAFs mainly because these farmers use very little pesticides.

A central issue with regard to this study is of course the use of pesticides, their environmental impact, incentives for reduced pesticide usage and the role that biotechnology can play in the reduction of pesticide usage and hence the implementation of more sustainable systems of crop production. In this regard, it is of paramount importance to note that (i) pesticide use is largely restricted to LSCFs, and (ii) in general, pesticide effects on the environment are not considered to be important to the sustainability of agriculture in Zimbabwe. The prevailing attitude is that pesticide use does not as yet pose a serious threat to sustainable crop production, and there is little awareness of the role that biotechnology can play in the implementation of sustainable crop production systems which are based on reduced use of pesticides. Instead, the dominant view is that biotechnology can contribute to improved crop production through the amelioration of specific constraints which have proved intractable to conventional plant breeding. Therefore, the prospects for the application of biotechnology are likely to be determined more by its contribution to increased productivity or a reduction in costs of production rather than an awareness of its contribution to sustainable crop production. The important policy implication therefore is whether the biotechnology initiatives vis-à-vis pesticide use should be pro-active or be delayed until the effects of pesticide use on sustainable agriculture become more obvious.

The important factors for reduced pesticide usage are the increasing cost of imported chemicals, concern over the effects of incorrect use on pest populations and the negative impact of pesticide residues on agricultural produce, particularly that which is destined for export. The most important observation is that environmental issues are not of great importance even in the large-scale, commercial-farming sector which is the major user of agro-chemicals. These observations imply that biotechnology intervention is more likely to gain acceptance by farmers if it can be related to production costs and acceptability of agricultural products. The promotion of biotechnology as a means for sustainable crop production vis-à-vis pesticide use appears to hold little promise.

A comparison of the national agenda in biotechnology and international efforts in promoting the development of biotechnology for sustainable agriculture indicates that there is little coherence, except perhaps in the case of the DGIS effort which is in line with government policy on promoting small-scale agriculture.

This lack of coherence emanates from their different perspectives as regards the role of agricultural biotechnology. On the one hand, the prevailing national view is that biotechnology intervention is desirable because it offers prospects for enhancing crop productivity through the amelioration of important constraints which have proved intractable to conventional solutions; sustainability vis-à-vis pesticide use does not feature prominently as a direct objective but rather as an indirect consequence of biotechnology intervention. On the other hand, international efforts in promoting biotechnology for sustainable crop production are founded on crop production practices in industrialised countries where large quantities of pesticides are commonly used. This difference in outlook has important implications for policy options regarding biotechnology in crop production. Perhaps the most important implication is that the development of biotechnology in Zimbabwe should be linked not so much to its contribution to sustainable agriculture vis-à-vis pesticide use, but rather to its potential as a technology that can lower costs of production, enhance productivity and reduce the dependence on agrochemicals for control of important pests.

In the final analysis, the nature of crop production in Zimbabwe will undoubtedly have a major effect on the contribution of biotechnology to sustainable agriculture. In the small-scale farming subsector in which little or no pesticides are used, biotechnology is likely to make little or no contribution to sustainable agriculture compared to pesticide usage and is therefore unlikely to contribute to environmentally "cleaner" systems of production than those presently in use. In contrast, there are real prospects for biotechnology to contribute to "cleaner" and more sustainable crop production in the large-scale, commercial-farming subsector in which large quantities of pesticides are used. However, because there is as yet little concern about the effect of pesticides on sustainability of crop production, the prospects for the adoption of biotechnological innovations by LSCFs will be determined not by environmental considerations, but, rather, by the ability of biotechnology to contribute to reduced costs of production and greater acceptability of their produce. Finally, it should be borne in mind that biotechnological intervention in the small- and large-scale farming systems can contribute to more sustainable crop production by providing protection against the ravages of pests and diseases.

APPENDIX: PERSONS CONSULTED

Mrs. Alexander	ACIA
Mrs. Chikowore	Grain Marketing Board
Mrs. R. Chikwamba	ENDA-Zimbabwe
Dr. J. Cole	Head; Biotechnology Department, Tobacco Research Board
Mr. B. Chisnell	Marketing Manager; Agricura
Mr. D. Gilliland	Research Manager; Cargill Seed Company
Dr. J. Jackson	Head; Horticultural Research Centre
Mr. R. Jarvis	Deputy General Manager (Development); Cotton Marketing Board
Prof. C. Keswani	Technical Consultant Pathologist; Plant Protection Research Institute, DR&SS
Dr. J. MacRobert	Research Manager; Agricultural Research Trust
Mr. L. Marufu	Head; Legume Inoculant Factory, DR&SS
Mr. S. Mutepfa	General Manager; Tobacco Marketing Board
Dr. J. Mushonga	Head; Crop Breeding Institute, DR&SS
Mr. P. Ndoro	Senior Economist; Commercial Farmers Union
Mr. G. Rabey	Head, Cotton Research Institute
Mr. G. Schepers	General Manager; Pannar Seed Company
Mr. W. Schrader	General Manager; Bayer Chemicals
Mr. S. Shepherd	Technical Manager; Windmill Fertiliser Company
Mr. J. Stocks	Extension Specialist; Tobacco Research Board
Mrs. D. Taylor	Entomologist; Commercial Farmers Union
Mr. R. Tattersfield	Senior Breeder; Seed Co-op
Mrs. J. Tiffin	Laboratory Manager; Tissucult
Mr. N. Wright	Economist; Commercial Farmers Union

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