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Agricultura Intensiva en la Islas del Caribe : posturas, coacciones y perspectivas

BIOTECHNOLOGY STRATEGIES FOR FRUIT CROP PRODUCTION IN THE CARIBBEAN

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ABSTRACT

The phasing out of preferential market arrangements with the advent of global trade liberalisation has led, in part, to a programme of Agricultural Diversification in the Caribbean, with a particular focus on the production of tropical fruits. It is envisaged that an increase in the production of tropical fruits, will not only better satisfy local consumption and tourism needs, but could also be used for export and processing. However, in order to realise these objectives, there is need for a great deal of research and development at the levels of both production and post-production. Modern Biotechnology provides the opportunity to carry out such research, not only in a shorter period of time, but in a more effective manner. The role of some of these new technologies viz. fermentation, plant cell and tissue culture, r-DNA, RFLP, RAPD, DNA-hybridization probes, monoclonal antibodies and anti-sense RNA in enhancing the production and post-harvest quality of fruits will be discussed. Whilst good scientific research is critical to the successful adoption of these technologies, adequate attention to the socio-economic, political and ethical issues is of equal importance.

INTRODUCTION

In recent times, there has been an increasing focus on the Agricultural Sector in the Caribbean by the politicians, economists, private sector individuals and companies, environmentalists and research scientists. This heightened interest is brought about by a number of factors. Three of the major ones are as follows:

(i) there is a widening of the existing gap between the demand and production of basic foods e.g. rice, peas and beans, root crops, meat and meat products and milk and milk products. This has led to a huge food import bill which many countries find difficult to service, due to dwindling foreign exchange reserves and earnings. There is therefore, a great need for increased agricultural productivity.

(ii) there has been a decline in the productivity of natural resources through (a) nutrient depletion, (b) loss of vegetative cover and genetic diversity, (c) soil erosion and (d) social and cultural disintegration. Such degradation in the environment occurred largely as a result of the Green Revolution which necessitated growing plants in monoculture and using extensive amounts of chemical pesticides and fertilizers. This has impacted negatively on wildlife, water quality and toxic residues entering the food chain. New systems of Agricultural Production are now in focus e.g. Low External Input Sustainable Agriculture. Such systems seek not only to halt the degradation of natural resources but to improve it where possible; not only to be ecologically balanced but also to be economically and socially balanced. In addition, new Agricultural systems will have to be adapted to localized changes in climatic patterns which are occurring as a result of increased levels of greenhouse gases in the atmosphere.

(iii) the advent of global trade liberalisation is very real and with it, will come the phasing out of preferential trade arrangements for target crops e.g. bananas and sugar. The approach in the Caribbean to deal with these phenomena is to introduce a programme of Agricultural Diversification. Such a programme seeks to intensify production of tropical ornamentals and fruits for export.It is a widely held view that the application of Modern Biotechnology is critical in the development of an agricultural system which is more productive, sustainable and diversified.

DEFINITION OF BIOTECHNOLOGY

While "Biotechnology" refers to a continuum of technologies with wide-ranging applications, which have been long established, in this paper, it refers to Modern Biotechnology which integrates Molecular Genetics, Biochemistry, Microbiology and Process Technology and which employs microorganisms, parts of microorganisms, cells and tissues of higher organisms to produce goods and services. This paper seeks to explore the possible applications of some of these new technologies in a programme of Agricultural Diversification with particular reference to the production of tropical fruits.

BIOTECHNOLOGIES FOR IMPROVING FRUIT CROP PRODUCTION

It is envisaged that increased fruit production in the Caribbean will not only better serve local consumption needs thus improving the nutritional status of the population, but could also satisfy tourism needs, enter the export market as a foreign exchange earner or be processed and made available for both the local and export markets. A programme which seeks to improve fruit crop production should seek to enhance not only productivity (quantity), but also keeping and processing quality and alternate use possibilities. The technologies selected for a discussion of their possible applications are : fermentation, plant cell and tissue culture, recombinant DNA (r-DNA), restriction fragment length polymorphism (RFLP), Rapid Amplification of Polymorphic DNA (RAPD), DNA-hybridization probes, monoclonal anti-bodies (MAB) and anti-sense m-RNA. While a few of these biotechnologies have developed to the stage where they are currently enjoying field applications, a large number may not have their impact until 2,000AD. Indeed, there are a few among us who are of the opinion that Biotechnology may have to await the next millennium before making an impact on overcoming hunger in the world.

Fermentation Technology

Traditional fermentation requires no control equipment and could be adapted immediately for processing of damaged, overripe fruits into wines. Another use of unsophisticated fermentors is in the production of biofertilisers e.g. microbial inocula (*Rhizobium*), total rhizosphere bacteria, *Azolla*, and VA mycorrhiza. Use of these inoculants for fruit trees could result in enhanced early growth hence reduced period of juvenility, higher yields, lower cost of production and reduced dependence on chemicals fertilisers.

Modern fermentation technology requires sterilisation equipment, a fermentor equipped with sensors and computers as well as high-quality technical expertise and support facilities. Until such requirements can be met in the region, it may not be wise to develop this technology on a large scale, although it could be a used to produce biopesticides which could substitute for chemical pesticides and alleviate the problems (e.g. possible harmful effects of toxic residues on fruits, on young children) that have now become associated with their use. It could also be developed to provide a wider range of alternate end uses for a particular crop e.g. bio-conversion of starch to sweet products, flavours and enhancers, processing of fruit juices, all of which would be value-added products.

Plant Tissue and Cell Culture

Tissue culture is probably the best-mastered of the new techniques, in the Caribbean, requiring little infrastructure. A laminar air flow hood, autoclave, nursery and green house are the major inputs. It is however, labour intensive and could be time consuming. Several fruit trees have already been grown in tissue culture e.g. oil palm, bananas and plantains, pineapple, tomato and date palm. It could therefore have wide-ranging applications in fruit crop production. Its major application has been for large scale production of plantlets which are disease - and virus-free. Use could also be made of somaclonal variation, induced mutagenesis and pollen and another culture in crop improvement programmes. Techniques to eliminate undesirable somaclonal variation are being developed. While many of the current plant transformation techniques require plant regeneration from cells or tissues, new ones (e.g. pollen transformation) are being developed which avoid this requirement. Development of these would be appropriate for the introduction of desirable genes into those fruit trees which to date are recalcitrant.

Plant cell culture is used for the production of secondary plant products. It circumvents large scale cultivation of the plants and removes constraints of adverse weather conditions, pest and diseases. It thus ensures a stable supply of consistent quality product and reduces land utilisation, which could then be used for the growing of fruit trees. This technology could have applications for the production of agricultural inputs e.g. herbicides and bio-pesticides. These would still be required to control weeds, pest and pathogens in fruit crop production, since even though the production of transgenic virus -, insect - and herbicide resistant crop plants is imminent, this prospect for tropical fruit trees is still far on the horizon.

This technology is being developed in the industrialized countries to produce substitutes for imports from the developing countries e.g. the protein sweeter, thaumatin; to substitute for sugar; saturated canola oil to substitute for tropical oils and synthetic cocoa butter to substitute for natural cocoa butter. In the same way, scientists and policy-makers in the Caribbean need to identify those imported inputs which could be produced using this technology. However, the likelihood of this technology being adopted in the near future is not likely since much basic research and development are still required for this technology, particularly in the areas of (a) the control of gene expression in cell culture; (b) the slow growth rates of plant cells and (c) susceptibility to contamination and the shearing of cells.

Recombinant DNA (r-DNA)

This technology which is the one still receiving most attention from the public, involves the insertion of pieces of DNA (genes) into a host's genome, thus altering the characteristic controlled by the inserted gene(s). At present, this technology is only applicable to plants for which regeneration protocols have been determined. To date, very little is known about the genes controlling characteristics important for fruit quality e.g. shape, size, texture, keeping quality, acidity, total soluble solids and fat content and, as stated earlier, regeneration protocols are available for only a few selected fruit trees. However data on genes controlling colour and amino acid, starch and sugar content are available, therefore the possibility of manipulating these characteristics exist. Research is needed to obtain the biochemical data for other characteristics which may be important for fruit quality.

RFLP

Host DNA is cleaved with restriction endonucleases and the resulting fragments, separated on agarose gels, are transblotted on to a membrane support (e.g. nylon or gene screen) and hybridized with known DNA probes. This technique may be used to: (a) map chromosomal regions coding for traits of economic importance, which can then be isolated, cloned and used in transformation experiments (b) assist the breeder to identify true hybrids and/or offsprings which have all or most of the desired genes (c) determine the identity or relatedness of individual plants (DNA fingerprinting). It is therefore a very powerful tool in a crop improvement programme. It is possible to identify an RFLP marker for male/female character in dioecious plants e.g papaw. Seedlings can then be screened prior to planting in the field.

This technology however is costly and has resource requirements not easily met in the Caribbean. These include skilled research and technical personnel, good reliable source of electricity, expensive equipment, radioisotopes, (although the less sensitive enzyme label may be used), perishable chemicals requiring a "cold chain" for delivery, bio-safety regulations and access to bio-information. With regard to the latter, it would be useful to establish linkages with institutions like the International Centre for Genetic Engineering and Biotechnology (ICGEB), the Centre for the Application of Molecular Biology to International Agriculture (CAMBIA) and International Services for the Acquisition of AgroBiotechnology Applications (ISAAA). It is hoped that with the setting-up of a Molecular Biology Laboratory at the Mount Hope Medical Complex in Trinidad, this technology would be developed, since much of the information needed is in the public domain.

In spite of the grave concerns expressed in many quarters about the deep involvement of the private sector (e.g. multinational co-operations) in Biotechnology, the major innovations (e.g. particle bombardment, gene markers, RFLP, PCR, RAPD) took place in the public domain (Universities and Research Institutes) and are therefore available without royalty charges.

RAPD

This technology employs polymerase chain reaction (PCR) which amplifies particular segments of the DNA molecule several fold. Instead of using primers of known sequence as in the case of PCR, random primers are used in the reaction. The amplified DNA is separated by gel electrophoresis. DNA with different nucleotide sequence generate DNA fragments of different lengths, reflected by a different banding pattern. The major application of this technology is for DNA fingerprinting of germplasm. It could be adapted immediately in the Caribbean which has the capacity to meet its resource requirements and where the need for germplasm conservation of plant species, including fruit trees, is of paramount importance.

DNA-hybridization

This technology forms the basis for the use of DNA probes. Such probes are single-stranded DNA fragments tagged with either a radioactive, fluorescent or enzyme label. Such probes hybridize with complementary DNA or RNA and may therefore be used in the identification, isolation and mapping of genes (RFLP). They could also be produced on a large scale either by cloning or by PCR for use as diagnostics in the detection of pathogens (e.g. viruses, bacteria) which would not be revealed immunologically.

Monoclonal Antibody (MAB)

This technique involves the fusion of an antibody producing cell (Mammalian B lymphocyte) with a cancer cell (myeloma). The resulting hybridoma, when stimulated by an antigen (virus, bacterium, DNA sequence, polysaccharide, peptide) produces an antibody, called monoclonal antibody. It is useful in the diagnosis of plant diseases and protein purification and therefore could be useful for studying organisms responsible for fruit spoilage and for protein analysis in fruits. To date, research on plant proteins has focussed on seed storage proteins and to a lesser extent, tuber storage proteins. Very little attention has been paid to protein quality and quantity, small though it may be, in fruits.

Antisense m-RNA

This technology has been successful in delaying the ripening of tomato and changing the colour of petunia flowers. It alters the normal plant metabolism by blocking the expression of the particular target gene. The identified gene is cloned, sequenced and a gene which codes for the antisense of the target RNA is synthesised and introduced into the plant's genome. The expression of this antisense m-RNA gene produces an m-RNA strand which is complementary to the host m-RNA. Complementary base-pairing takes place between both sense and antisense strands which blocks further expression of the genes. This technology could have a tremendous impact on fruit production by reducing post-harvest bio-degradation processes and changing fruit colour. However the constraints for this technology are the same as those outlined for that of r-DNA i.e. protocols for transformation and regeneration of the host plant must be established and required infrastructure (equipment, chemicals etc.) must be in place.

SOCIO-ECONOMIC, POLITICAL AND ETHICAL ISSUES

Before arriving at any decisions regarding the adoption of Biotechnologies for Agricultural Development, the opinions and support of the Scientist, donor agency, policy-maker and the farmer must be sought. The baseline for the farmer is profitability; he may, therefore, be dubious about adopting a new high yielding variety which costs more from the company providing it, yet fetches lower prices due to overproduction - benefits go to the industrialist and the consumer at a cost to the farmer. Similarly, the development of a herbicide resistant sugar beet by a particular company would necessitate the farmer purchasing both planting material and herbicide from the same source allowing no room for negotiation.

While farmers may see the benefits of growing insect resistant transgenic plants, they would hardly do so if because of media scare and lobby groups the public refuses to buy such products. In countries with overproduction of milk, farmers would be reluctant to use bovine somatotropin. In addition, there has been a report that such enhanced milk production causes a greater incidence of mastitis, requiring greater use of antibiotics. It also suggested that toxic levels of these substance may be present in both milk and meat. Because of these concerns, the release of genetically modified organisms in the environment and the use of biotechnological products are currently being debated internationally.

We are still mindful of the ill-effects of the Green Revolution on the environment and on resource-poor farmers, particularly women farmers. The green revolution failed to recognize the importance of scientific research and public policy to the fate of small farmers and the impact of this on the structure and well-being of the society. It is therefore hoped that with the gene revolution more pro-active social research and analysis will take place and greater emphasis put on evaluating the outputs. Scientists can no longer, in their enthusiasm, get on with research based on scientific merit with no regard for its later use or benefit. Research priorities must be identified based on the needs of the end-users i.e. farmers and consumers.

A further area of concern in Biotechnology is the patenting of genetic material, intellectual property rights and farmer's rights - this is still actively being debated.

Based on the above it seems clear that there is an urgent need to set up an interdisciplinary team consisting of scientist, farmer, social scientist, policy-maker, consumer, economist to develop a Regional Policy for Biotechnology which will address the following concerns : Biosafety; Bioinformatics; Patenting and Intellectual property rights; linkages with International and Regional Institutions; relations between Public and Private Sectors and large scale and subsistence farmers. In addition, a similar team in each country of the region should develop national policies which would take into consideration the special needs and circumstances of that country and place greater emphasis on determining research priorities. In arriving at these policy statements, the most pertinent question that must be borne in mind is: "How do we ensure that Biotechnology research results are fully exploited without further endangering our already fragile planet?

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