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ECONOMIC POTENTIAL OF BIOTECHNOLOGY IN AGROFORESTRY

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ABSTRACT

The practice of agroforestry date back 7'000 years ago. Examples of agroforestry practices are found throughout the world. Biotechnology will play a key role in the development of agroforestry. Improvement of plant breeding by biotechnological methods is expected by 1997 with a reduction in breeding time of 10-20%. With the application of biotechnology growers can reduce chemical fertilizer by 70% and still increase yields. The transgenic plants can offer protection all season long independent of the weather and affects only crop-attacking pests. Insertion of antisense sequences on the germ give improved postharvest qualities in crop plant and minimize losses in farm income. Biothecnology provide less environmentally deleterious reactions, to be applied in the management of agroforestry wastes.

Long before man was created on earth forms of agroforestry existed:

"Let the earth produce all kinds of plants, those that Bear grain and those that bear fruit....,Then the Lord God planted a garden in Eden. He made all kinds of beautiful trees grow there and produce good fruit." (Genesis 1:11 , 2:2-9).

" It is he who produceth Gardens, with trellises and without,and dates, and tilth produce of all kinds, and olives and pomegranates, Similar (in Kind) and different (in variety)." (El-Anaam 141).

The practice of agroforestry date back to the neolithic period 7'000 years ago where tree species and agricultural crops were cultivated in close combination (Spurgeon 1987)). Examples of agroforestry practices abound throughout the world. In Central America, farmers grow a canopy of coconut or papaya with a lower layer of bananas or citrus, a shrub layer of coffee or cacao, annuals crop such as maize and a ground cover plants like squash (Wilken, 1977). Asian farmers in the Philippines, while clearing the forest for agricultural use, intentionally leave certain trees to provide construction wood, medicines,cosmetics and to protect the soil (Conklin 1957), while in Africa grain crops and vegetables are grown together under scattered trees (Forde 1937).

Forty seven percent of the world economically active population is employed in the Agriculture sector (FAO 1988). By the year 2000, 1.7 Billion people will be living in over 60 countries, who's governments will be unable to feed their populations from their own lands due to low agricultural inputs (Anonymous 1986). Three quarter of them will be in Africa and southwest Asia were the majority of the population are members of farm families. The world wide arable land per capita was estimated in 1975 at 0.77 acres; it is expected to be only 0.37 acres by the year 2000 because of the great soil erosion, deforestation and desertification. In order to prevent future disaster in rural development, the United Nations Conference on Desertification in Nairobi, Kenya (1977), formulated a "Plan of Action " which highlighted the role of sustainable resources management and the importance of forestry within integrated land use. Agroforestry can offer an excellent means of land management, particularly for small scale farmers, and at the same time provides poor farmers with needed products of all kinds especially for food,feed,fuel wood and materials, with no radical change in their life style.

"Agroforestry must not be an attempt to return to storage practice or to cap people at low levels of development on external inputs. Agroforestry will have to be opened to dynamic technical progress, and is to be made a land-use concept suitable for spear heading development by its holistic systems approach" (Von Maydell 1987).

Biotechnology will play a key role in the development of Agroforestry. It will replace the classic practices of breeding

Plants and trees; particularly with gene manipulation technology, and tissue culture a large number of plants can be produced free of disease and resistant to disease pests and environmental stress. Gotsch & Rieder (1989) conducted an international survey of plant and microbial biologists, plant breeders and product development experts and managers on the future importance of biotechnology in arable farming. The respondents expected improvement of plant breeding by biotechnological methods with a reduction in breeding time of 10-20% by 1997.

Agroforestry system are relatively complex and their analysis can be difficult. There is a bewildering array of agroforestry systems world wide; over 2000 species of multipurpose trees are being used in various systems and the systems vary from relatively simple with two or three components,to the complex homegardens which may contain up wards of 50 species, plus animals and fish (Fernandes and Nair 1986).

PLANT QUALITY

The most important aim of biotechnology is the creation of transgenic plants with new and/or altered heritable and economically valuable traits . In cereals and grain legumes, the composition will obviously increase their nutritive value. The nutritive value of **Solanum tuberosum** tubers could be improved with the introduction **in vitro** of a synthetic gene sequence coding for a protein high in essential amino acids (about 80%), which would result in the production of potatoes with proteins balanced in its content of essential amino acid (Yang et al. 1989).

Feed quality can be improved by introducing natural high specific amino acid protein genes under the control of storage protein promoters, e.i. barley with high lysine content of B-hordein storage proteins. Plants have already been engineered to produce protein high in sulfur and resistant to rumen degradation to improve wool growth in sheep (Higgins et al. 1989).

In contrast to many other agricultural commodities, oil crop prices and uses are determined by the quality and /or quantity of the oil. An extreme example is the approximately 50-fold price differential between soybean oil and cocoa butter (Somerville 1990). Increasing the oil content of the rapeseed crops by 1% would be worth approximately 10 kg oil/acre. A Canadian Company was able to produce new lines of rapeseed exhibiting oleic acid levels above 85% and linolenic acid levels below 3% in its oil which is ideal for food processing, lower saturated fat and longer shelf life (Gawen 1990). A new soybean was developed, at Iowa state university, that may yield a vegetable oil to challenge canola and other vegetable oils with low saturated fats and it has a higher percentage of stearic acid than canola.

Environmental stress have large impact on average yields for crops, as much as 75% of the loss in yield could be attributed to unfavorable environments such as drought and salinity (Boyer 1982). Regenerated plants from calluses of rice cultivars selected from media containing 1% Nacl or 50% sea water grow better than any other cultivar (Subhashini & Reddy 1989). Plant breeders in Cambridge, Uk, have crossed wheat with sand couch grass to produce a strain of wheat which can tolerate salty conditions, the tolerance of the hybrid will be extended to waterlogging; so that it can be grown on saline, poorly drained land (Macklin 1989).

BIOTECHNOLOGY AND PROPAGATION

Cloning, vegetative propagation, is the most efficient method to propagate trees, horticultural plants and major agricultural crops. Over the last 15 years, tissue culture has found wide commercial application in the propagation of plants (Anonymous 1988), and the preservation of biological material in the form of **in vitro** embryos, clonal or somatic tissue (Thorpe 1981).The advantages of plant tissue culture may be divided into two aspects: a) Logistical aspects such as reduced space requirements, year round and speed of propagation, and low costs. b) Manipulative aspects including improved plant characteristics, and the selection of high yielding commercial strains free from pests and diseases (Deans and Svoboda 1990).

The most common example on the economic use of plant tissue culture is the production of pathogen-free potato plantlets and tuberlets. Imported seed tubers are an important part of the cost of production of potatoes in most climatic zones of the world.Due to technological improvements in seed production, importation of tuber seed has been largely reduced in Brazil and completely stopped in Argentina (Dodds and Horton 1990). The korean Government improved its seed potato program by using tissue culture to produce virus-free seeds. Potato yields per acre doubled with an estimated increase in farmers incomes of approximately 20 million dollars, every dollar spent on the program generates annually 25 dollar in increased farm incomes (Horton et al. 1988).

BIOTECHNOLOGY AND FERTILIZER

An Agroforestry system with high plant productivity must rely heavily on the input of nitrogen fertilizer. Chemical fertilizers are costly in terms of price and application. The world produces about 75 million mt. of chemical NH_3 for fertilizer and around 1-2% of the world's annual fossil fuel consumption is required for this purpose (Elkan 1990). The diverse procaryotic microorganisms are able to fix nitrogen directly from the atmosphere approximately 175 million mt/yr, in every environment.Symbiotic systems are more efficient than BNF free living bacteria in nitrogen fixation to a rate of 450 kg/ha/yr (Elkan 1990).

With the application of plant molecular biology using symbiotically altered mutants of plant, growers can reduce chemical nitrogen inputs by 70% and still increase yields. MicroBio, a UK company, has developed a free-flowing granule formulation for Rhizobium inoculant. This inoculant, applied in the seed furrow at planting, maximizes the natural nitrogen fixing capacity of green beans with an average yield increases of 12% despite 60-70% reductions in the use of nitrogen fertilizers.

The mutant algae, Azolla, was found to increase rice growth as much as commercial fertilizers; it produces ammonia only when surrounding rice plants need it, which give rice growers a self-regulating fertilizer system, decreases ground water and surface water contamination and is cheaper and needs less labor work than chemical fertilizers. **Azolla pinnate** was able to grow in soil mixed with industrial waste from a chlor-alkali factory, and added significant amounts of nitrogen and organic carbon to the growing medium (Nanda et al.1989).

The vesicular-arbuscular mycorrhiza **Pisolithus tinctorius** ,a symbiotic fungus-root association,can greatly increase the utilization of phosphate present in soil,improve seedling survival and growth on good quality reforestation sites especially during droughts. On disturbed sites,ectomycorrhizae enhanced absorption of elements ,and reduced the absorption of toxic elements in contaminated soils (Hayman 1981, Marx and Cordell 1988). **Pisolithus tinctorius** forms ectomycorrhizae with over 100 species of trees,it have a wide geographical distribution and range of environmental tolerance (Marx 1981). According to Cordell et al.(1987),it costs about 1 cent per plant for artificial inoculation of ectomycorrhizae to nurseries,and a 2.5% improvement in survival is necessary for inoculation to be self financing. If survival is improved 5.0% this technology would generate a saving of 1 cent real cost per seedling.

BIOTECHNOLOGY AND PESTS CONTROL:

The transgenic plants offer protection all season long, this protection is independent of the weather and affects only crop-attacking pests. The advantages of genetically engineered protection over exogenous chemical control are numerous, it protects the plant tissues difficult to reach with sprays,the pests are affected at their most sensitive stage, and the protectant is confined to the plant tissues, biodegradable and usually non-toxic to man and animals (Boulter et al. 1989).

Numerous successful attempts have been reported for producing insect-resistant, transgenic crop plants by genetic engineering . Some relied on the natural defence mechanisms which have evolved in plants to control herbivorous insects, such as the protease inhibitors from cowpeas (**Vigna ingniculta**) which are antimetabolic to a wide range of insects (Hilder et al. 1989).Others cloned genes from microorganism which produce endotoxin toxic to the larvae of certain lepidopteran pests, but are harmless to beneficial insects, animals and humans. The potential market of the transgenic plant to control bollworm in cotton is estimated at 550 million US dollars (Hebblethwaite 1989).

Transgenic tobacco plants engineered to express either the potato X virus coat protein (CP+) or the antisense coat protein transcript (CP-antisense) were protected from infection by

PXV (Hemenway et al.1988). Commercial potato cultivar resistant to mixed virus infection were engineered using the coat protein (CP) genes of potato X potex virus (PVX) and potato Y polyvirus (PVY) (Lawson et al 1990). Hull (1990) argued that there was a risk that when engineering resistance to one virus, other viruses might interact with the recombinant DNA introduced or become encapsulated in introduced coat proteins and a new potentionally dangerous virus might arise.

The genetically engineered herbicide-tolerant crop plants are expected to increase agricultural dependence on chemical herbicides that pollute the environment and contaminate food and water supplies. The use of crops tolerant to herbicide "Basta" would increase the world sales of that herbicide by 200 million US dollars a year. Goldburg et al. (1989) argues that with herbicide-tolerant crop plants, once commercially widely used, the exchange of herbicide-tolerance genes between the commercial crop and weedy relatives could result in the need for more chemical herbicides to control herbicides-resistant weeds.

BIOTECHNOLOGY AND MARKETING:

Crop plant losses in farm income is a result of many factors of which postharvest quality and marketing are significant. In the US the total farm income losses was estimated to about 1.0 billion US dollars in an average year. Insertion of antisense sequences on the germ give improved postharvest qualities in crop planted . Genetically engineered tomato lines that express a polygalacturonase (PG) antisense RNA exhibit 10% of the normal levels of PG activity. The depolymerization of the pectin wall of the tomato is prevented by the reduced PG levels and the fruit has improved firmness and can survive long journeys to market. Antisense-modified ornamental plants for flower color and patterns and virus-resistant plants are other potential applications of this technology. The market potential of antisense-modified plants is estimated to be about 406 million US dollars by 1999 (Business Communications Company, Inc. Study C-109).

Even though the genetically engineered seed might be marketed at double the price of classic varieties, farmers will save in pesticide and fertilizer applications and will increase their income through higher yields and better quality of non toxic products.

BIOTECHNOLOGY AND THE ENVIRONMENT:

The most important natural activity in the environment is the biological degradation of lignocellulosic materials such as agricultural wastes and wood to carbon dioxide,water, and humic substances.The challenge of biotechnology lies in its potential to provide less environmentally deleterious reactions ,to be applied in the management of agroforestry wastes. Over 50% of the biomass,containing hidden energy-rich carbohydrates, is wasted or under-utilized.

Through the use of high pressure steam to break the bond between lignin,cellulose and hemicellulose,the StakeTech System converts biomass materials into nutrious feed, chemicals and fuels.It takes 1 lb. of waste biomass or equivalent energy to change 9 lbs. of biomass into higher value products without the use of chemical additives that could contaminate the environment (Yu , personal communication).

Million of tons of microbial protein are annually produced all over the world, most of this industry relies on the liquid paraffins of oil. Recently, operative technologies was developed for continuous yeast culture under non-sterile conditions using hydrolysate of wood and other plant wastes to produce feed containing 60 to 62% protein,18% carbohydrates and 16% lipids (Muromtsev 1990) . A mixed culture of **Cellulomonas sp** and **Bacillus subtilis** was grown using alkali-treated milled maize cobs as a carbohydrate source to produce forage protein (Perotti and Molina 1988).

The production of biogas from dried banana peeling is economically feasible. Biogas comprising 70% methane was obtained after the peelings were aerobically fermented for 48h before placing in digester bottles (Hasan et al. 1989).

BIOTECHNOLOGY AND DEVELOPING COUNTRIES:

The transfer and application of biotechnology to developing countries depend mainly on developing country economic resources. Tissue culture technique for plants propagation seems to be appropriate to many developing countries. There are centers in

Africa, Asia, and Latin America focusing on the production of pathogen free plant materials.

The United Nations' Food and Agriculture Organization carried out a regional study in Latin America and the Caribbean (Anonymous 1990). Most (63.4%) of the 153 laboratories interviewed are interested in **in vitro** culture, with 11.4% performing germplasm conservation, 10.1% in plant health diagnostics and 8.6% in the field of genetic engineering. The studies revealed constraint factors to the development of plant biotechnology in Central and South America as the lack of training in advanced biotechniques, the limited operational budgets and the absence of a regional cooperative network.

In Conclusion:

While agroforestry is a complex system, to apply biotechnology to increase its productivity and maximize economic returns requires that each component be improved for those characteristics that best serve the system as a whole.

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