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Standard Review

Transgenic plants: Successes and controversies

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Applications of herbicides, pesticides, and fertilizers have greatly increased crop yields in the past. More recently, however, crop yields are barely keeping up with world growth, hence the need for new approaches. Agricultural biotechnology may likely play a key role in the race to feed the world's expanding population with fewer inputs and on less and less available land. Genetic engineering of plants represents the next stage of evolution in our continuing efforts to improve plants used for the production of food and animal feed. Agricultural biotechnology is a powerful technique offering great potential for agricultural sustainability and safe production of foods with increased nutritive value, improved flavour, prolonged freshness, and even disease-fighting properties, but it is not without controversy. The potential for the transgenic crops to alleviate human hunger, and the controversies which are invariably based on visions of the new technology from widely different ethical perspective which have divided both the public and the scientific communities are discussed. But, critical to its adoption and acceptance is by providing choice and accurate information to consumers from scientists, policy makers, industry and the press. The present review addresses the prospects of the technology, and the polemics concerning its adoption.

Key words: Transgene, pharmaceutical crops, risks, prospects and controversies.

INTRODUCTION

Biotechnology is not new. Cheese, bread, alcoholic beverages and yoghurt are products of (traditional) biotechnology and have been known for centuries. But recent developments in molecular biology have given biotechnology new meaning, new prominence, and new potential. It is (modern) biotechnology that has captured the attention of the public and can have a dramatic effect on the world economy and the society. Genetic engineering which is an example of modern biotechnology is the process of transferring individual genes between organisms or modifying the genes in an organism to remove or add a desired trait or characteristic. Through genetic engineering, genetically modified (GM) crops or organisms are formed. These GM crops or GMOs are used to produce biotech-derived foods. It is this specific type of modern biotechnology that seems to generate the most attention and concern by consumers and consumer groups. What is interesting is that modern biotechnology is far more precise than traditional forms of biotechnology. It allows for the transfer of only one or a few desirable genes, thereby permitting scientists to develop crops with specific beneficial traits and reduced undesirable traits. Traditional biotechnology such as cross-pollination in corn produces numerous, non-selective changes.

Actually, it can more accurately be said to originate with the publication of the Cohen and Boyer paper in 1973. Since then, the field of agricultural biotechnology (Ag Biotech) has grown rapidly over the last half-century. Modern agricultural biotechnology has offered opportunities to produce more nutritious and better tasting foods, higher crop yields and plants that are naturally protected from diseases and insects. Genetic modifications have produced fruits that can ripen on the vine for better taste, yet have longer shelf lives through delayed pectin degradation. Similarly, introducing genes that increase available iron levels in rice three-fold is a potential remedy for iron deficiency, a condition that affects more than two billion people and causes anemia in about half that number. Most of the today's hard cheese products are made with a biotech enzyme called chymosin, produced by genetically engineered bacteria which are considered more pure and plentiful than its naturally occurring counterpart, rennet, which is derived from calf stomach tissue (Kass, 2005). More so, the starch content of Russet Burbank potato has been successfully increased in 1992, by Monsanto Company through gene transfer. Such a gene from a bacterium increased the starch content of the potato. The advantage is that the higher starch content reduces oil absorption during frying , thereby lowering the cost of processing French fries and chips, with a concomitant reduction of the fat content in the finished product.

Sub-Saharan Africa is considered one of the world's food insecure regions. The available statistics indicates worsening scenario. Africa's overall food production capacity is said to be increasing at the rate of 1.4% while its population is expanding at about 2.4% per year (FAO, 2000). The continuing decline in food production will have to be reversed if massive food insecurity, poverty, social and political instability are to be averted. Green revolution type technologies requiring increased land, water and fertilizer use may not be appropriate for sub-Saharan Africa due to resource limitations and population pressure. Biotechnology application may be considered to be more appropriate to solving our agricultural and poverty reduction problems, so as it minimizes inputs while increasing yields (Alhassan, 2002). Reduced pesticide use can mean more abundant and diverse animal and beneficial insect populations, cleaner water, fewer containers for disposal, and reduced fuel use for pesticide applications. Improved weed control enhances conditions for no-till farming, which greatly reduces soil erosion and pre-emergent pesticide use. Improved crop yields mean that the acreage available for production is used in a more efficient way (Bridges et al., 2003). Biotechnology is currently changing the way plants and animals are grown, boosting their value to growers, processors, and consumers. The most common transgenic varieties available today are those that tolerate proprietary brands of herbicides, and those that contain insecticide genes.

In the developing nations, small and peasant farmers are the primary producers of staple foods. This sector, which is so important for food production, is itself characterized by poverty and hunger. Thus rural areas in the developing nations are today characterized by extreme inequalities in access to land, insecurity of land tenure and in the quality of land farmed. Furthermore, by keeping wages and living standards low, the elite guarantees that healthy domestic markets will never emerge. The result is a downward spiral into deeper poverty and marginalization. One irony of our world is that food and other farm products flow from areas of hunger and need to areas where money is concentrated.

APPLICATIONS OF BIOTECHNOLOGY IN FOOD PROCESSING

Historically, the food processing industry has had to accept and adapt to heterogeneous raw materials.

Biotechnology can be used to better tailor food crops to meet food processing and consumer needs. Tissue-culture techniques are being used to select or construct crop varieties with improved functional, processing, or nutritional characteristics. Plant tissue culture techniques can be used to produce food flavour and colouring ingredients. These methods could potentially replace production and extraction of these ingredients from plants (Fraley, 1991; Harlander, 1991).

Genetic engineering is also a means of altering food characteristics. Genes coding for enzymes involved in starch and lipid biosynthesis are being isolated and cloned, enhancing the prospects of engineering plants with specific composition of starch and oil. Genes coding for floral pigment pathways are also being isolated. Plants potentially can be engineered to produce pharmaceuticals such as blood clotting factors and growth hormones. For example, oilseed rapeseed has been genetically engineered to produce encephalin (Vandekerckhove, 1989). In addition antisense technology is being used to eliminate toxins allergenic compounds, or off-flavour components in plants, and to delay ripening of tomatoes (Fraley, 1991). An elegant study by Brookes and Barfoot, (2005) revealed that GM technology has had a very positive impact on farm income derived from a combination of enhanced productivity and efficiency gains (Table 1). In 2004, the direct global farm income benefit from GM crops was $4.8 billion. If the additional income arising from second crop soybeans in Argentina is considered, this income gain rises to $6.5 billion. This is equivalent to adding between 3.1 and 4.2% to the value of global production of the four main crops of soybeans, maize, canola, and cotton - a substantial impact. Since 1996, farm incomes have increased by over $19 billion or $27 billion inclusive of second-crop soybean gains in Argentina.

Biotechnology is also being used to improve micro-organisms used as vegetable starter cultures and in brewing and baking (that is, organisms used in making sauerkraut, pickles, olives, soy sauce, wine, beer, and bread) such that these organisms tolerate different temperature and pH ranges. Similar work is being conducted with microorganisms used to produce food ingredients such as acetic acid, citric acid, ethanol (Ubalua, 2007), niacin, vitamin B 12, xantham gum, and mono-sodium glutamate. In addition, genetically engineered enzymes are being developed to treat food wastes (Harlander, 1991). Application of biotechnology in the development of methods to assay levels of pathogens toxins, and chemical contaminants in raw ingredients and final products have being perfected. DNA probes and poly and monoclonal antibody kits are beginning to replace traditional bioassay methods; an example is the detection of pesticide residues in food with monoclonal antibody kits. Molecular breeding by applying genetic engineering in the production of medicines, dyes, insecticides, flavours and fragrances is in this respect a promising approach (Verpoorte and Memelink, (2002).

Table 1. Global farm income benefits from growing GM crops, 1996-2004 (US$ million).

Trait	2004 increase in farm income	1996-2004 increase in farm income	2004 farm income benefit as % of total value of production of these crops in GM adopting Countries	2004 farm income benefit as % of total value of global production of these crops
GM HT Soybeans	2,440 (4,141)	9, 300 (17, 351)	5.6 (9.5)	4.0 (6.7)
GM HT maize	152	579	0.6	Less than 0.5
GM HT cotton	145	750	1.4	0.53
GM HT canola	135	713	8.3	1.34
GM IR maize	415	1, 932	1.4	0.8
GM IR cotton	1, 472	5, 726	10.5	5.3
Others	20	37	N/a	N/a
Totals	4, 779 (6, 480)	19, 037 (27, 088)	5.3 (7.2)	3.1 (4.2)

Note: HT = Herbicide tolerant, IR = insect resistant, others = Virus resistance papaya and squash, rootworm-resistant maize. Figures in parentheses include second-crop benefits in Argentina. Totals for the value shares exclude “other crops” (that is, relate to the four main crops of soybeans, maize, canola, and cotton. Source: Brookes and Barfoot, (2005).

Genetic engineering of a secondary metabolic pathway aims to either increase or decrease the quantity of a certain compound or group of compounds (Dixon, 2001; Facchini, 2001; Verpoorte et al., 2000; DellaPenna, 2001). To decrease the production of a certain unwanted (group of) compound (s) several approaches are possi-ble. An enzymatic step in the pathway can be knocked out, for example, by reducing the level of the corresponding mRNA via antisense, cosuppression or RNA interference technologies, or by over-expressing an antibody against the enzyme. The antisense gene approach has been successfully used for changing flower colours. Other approaches include diversion of the flux into a competitive pathway or an increase in the catabolism of the target compound (Verpoorte and Memelink, (2002).

PHARMACEUTICAL CROPS

The benefits of gene manipulations in agricultural production has obvious overwhelming potentials but with unconfirmed risks and controversies. Crops are being genetically engineered to produce a wide variety of drugs, vaccines, and other pharmaceutical proteins. Although they may open the door to less expensive and more-readily available drugs, there is concern regarding the potential for contamination of human food and livestock feed, as well as environmental harm (CSA, 2007). In light of the many pros and cons, three major approaches: the precautionary approach, risk analysis, and cost-benefit analysis could be used to move the debate about pharmaceutical crops forward. Today, however, crops are now being turned into factories producing not just food, but drugs, insulin, vaccines, enzymes, and antibodies. The first step in using crops to produce pharmaceutically active proteins is the synthesis or isolation of genes that code pharmaceutical proteins, followed by the transfer of those genes into the DNA of crop plants. These transferred genes, or “transgenes”, can potentially come from a different plant species, an animal, or a bacterium. The genetically modified crops are then cultivated and harvested. In most cases, the crop-produced pharmaceutical protein is extracted, purified, and possibly modified further before it is administered to humans or livestock. In some instances, however, crops are being engineered so that a vaccine can be delivered through the direct consumption of leaves, fruits, or other plant parts, without the cost and the inconvenience of extracting the proteins and delivering them via pills or injections (Sala et al., 2003).

Benefits of pharmaceutical crops

The driving force behind pharmaceutical crops is the possibility of quick production of large quantities of drugs and vaccines, with the hope of reducing costs and increases the much needed pharmaceuticals (Giddings et al., 2000; Fischer et al., 2004; Horn et al., 2004; Ma et al., 2003; Ma et al., 2005). The potential products of transgenic plants include blood thinners, haemoglobin, insulin, growth hormones, cancer treatments, and contraceptives. Products already available include plant-produced vaccines for hepatitis-B, cholera, rabies, malaria, and influenza. Presently, genetically modified maize (corn) to produce lipase, a digestive enzyme used to treat patients with cystic fibrosis is under development. Others are arthritis and other autoimmune diseases. The use of maize, banana, tomatoes, carrots, and lettuce as possible oral-delivery mechanisms for such vaccines was reported by Sala et al. (2003), because these foods can be eaten raw, thereby avoiding the protein denature-tion that typically occurs during cooking. Such eliminates the need for refrigeration, which limits the usefulness of which limits the usefulness of certain vaccines in many parts of the world.

Currently, the method of choice for manufacturing many drugs is by laboratory cell culture of bacteria, yeast, or animal cells. There are many draw backs to this technique of mass producing drugs such as outlined below:

- Cell cultures requires constant monitoring and sampling, as it tends to require precise parameters in order to produce large amounts of protein
- Expansion is very costly and laborious, as new equipment is required and also space to store the equipment
- In order to retain biological activity, many proteins require modifications (addition of sugars, for example), some of which are only performed by mammalian cells and
- Most cells need to be ruptured (not a trivial procedure if you consider the size of modern bioreactors) to isolate and purify the protein of interest, which is much more difficult than purifying proteins from the blood or milk of an animal (Jamie, 2005).

Presumably, plants are an attractive alternative because they could potentially produce greater yields. This is especially important for monoclonal antibodies (such as entercept, which is used to treat rheumatoid arthritis) because current production methods cannot keep up with increasing demand (Elbehri, 2005). Moreover, faster and less expensive production could reduce prices for consumers. Another major benefit of utilizing plants is the reduced risk of disease transmission, in view of the concern that drugs produced via mammalian cell cultures or animal milk could facilitate the movement of certain viruses to humans (CSA, 2007). Generally, grain crops are favoured because protein yields from the large seeds of maize, rice and barley are typically much higher than those obtained from leaves and other vegetative parts. In addition, pharmaceutical proteins can remain stable in dried grain for several years, compared with the much-reduced stability of these same proteins in leaf tissues. Maize is generally recognized as safe for ingestion by the U.S. Food and Drug Administration (FDA) and therefore can be used as an inactive carrier, suitable for drug delivery. Fischer et al. (2004) opined that a growing number of companies are focusing on tobacco, or even mosses, algae, and duckweed, as platforms for pharmaceutical production. However, these plants, pose risks of their own that must be considered, though algae and duckweed, if cultivated would have greater potential than highly domesticated crop species to escape from cultivation.

CONTRIBUTIONS OF RECOMBINANT DNA TECHNOLOGY

Biotechnology is offering innovative possibilities for increasing crop and livestock production and for the protection of the environment by the reduced use of chemicals. The major thrust is presently directed towards medicine, industry, and agriculture in the industrialized countries, with significant investments by trans-national companies. The specificity with which genes can be examined and manipulated opens up real opportunities to tailor-made new plants, and new livestock for specific environment. While traditional plant breeding involves the transfer of large numbers of new genes into a crop followed by cycles of backcrossing and de-selection of undesired genes and traits, genetic manipulation can now be done in the laboratory. Biotechnology is thus comprised of a continuum of technologies, ranging from the long-established and widely used technologies, which are based on the commercial use of microbes and other living organisms, through to the more strategic research on genetic engineering of plants and animals. Genetic engineering evolved from an understanding of how cells function naturally, particularly how the genetic material (DNA) codes for the production of proteins essential for the life of the cell. Based on this understanding, other scientists then devised a series of new techniques, collectively called recombinant DNA technology, to allow the manipulation of these processes in the cell. The major limitation is to identify genes which, when transferred with appropriate molecular controls, will confer agriculturally useful traits on the recipient microorganism, plant or animal. Biotechnology is said to be “the first business with enough glamour to persuade eminent scientists that the entrepreneurial spirit and academic respectability are not mutually exclusive. It has been used in a number of crops for several years, and more genetically enhanced products are expected to be on the market in the coming years. By increasing a crop’s ability to withstand environmental factors, growers will be able to farm in parts of the world currently unsuitable for crop production. Along with additional food, this could also provide the economies of developing nations with much-needed jobs and greater productivity.

Biotechnology will also enable growers to produce further enhancements in plant varieties. This would allow for the possibility of increasing the agricultural gene pool that billions of people rely on for basic foodstuffs.

IMPACT OF TRANSGENIC PLANTS ON SOIL AND MICROBIAL COMMUNITIES

Transgenic plants are those plants whose heredity DNA has been augmented by the addition of DNA from a source other than the parental germplasm, using recombinant DNA techniques. They possess novel genes that impart beneficial characteristics such as increased nutritive value, improved flavour, prolonged freshness and even disease-fighting properties. The debate surrounding the use and commercialization of genetically modified crops is emotive and presently unabating. The “perceived” risks include plant invasiveness or dispersal of the plant itself into the native ecosystem causing indirect impacts on the diversity of crops, gene flow through pollen transfer or through horizontal gene transfer with associated microorganisms, development of resistance in target organisms, and non-target effects on native flora and fauna including effects on the biodiversity of beneficial and antagonistic microorganisms (Eastham and Sweet, 2002; Nielsen et al., 2001; Wolfenbarger and Phifer, 2000; Riba et al., 2000).

One of the primary concerns about genetically modified crops is the presence of clinically important antibiotic resistance gene products in transgenic plants that could inactivate oral doses of the antibiotic. Another concern is that the antibiotic resistance genes could be transferred to pathogenic microbes in the gastrointestinal tract or soil, rendering them resistant to treatment with such antibiotics (Daniell et al., 2001). Though evidence for the persistence of transgenic plant DNA exists, the transformation of plant DNA to native soil microorganisms has not been found. Several studies attempted to assess natural transformation from plant DNA to soil microorganisms under field conditions and determined that while free DNA persisted in the soil, no proof of a plant gene being transferred to soil bacteria was found (Widmer et al., 1997; Paget et al., 1998; Gebhard and Smalla, 1999). Oger et al. (1997) demonstrated that genetically engineered plants might alter their biological environment, more precisely the root-associated bacterial populations. A response in the composition of the microbial population was observed after the introduction of a single genetic trait into the plant genome. According to Dunfield and Germida in 2004, the effect of plant variety on the microbial community at one field site was sometimes entirely different at another field site, suggesting that the environment will play a major role in determining the potential ecological significance of growing genetically modified plants. Furthermore, a time course study examining genetically modified plants over an entire field season suggests that changes to the microbial community structure associated with genetically modified plants are not permanent. Collectively, these results seem to indicate that microbial diversity can sometimes be altered when associated with transgenic plants; however, these effects are minor in comparison with environmental factors such as sampling date and field site.

HEALTH AND ENVIRONMENTAL RISKS

Microorganisms are ubiquitous in nature. Many are simply harmless commensals, and majorities are beneficial symbionts that protect us from pathogen colonization, synthesize vitamins, and contribute to proper functioning of the intestine. They are known as microbiota or the body’s normal flora. Regardless of the mode of entry, once inside the body, these pathogenic microorganisms may overcome our powerful defense mechanisms, multiply and release their enzymes, toxins and molecules, thereby causing diseases. Microorganisms have always been employed to improve the quality of life, to the extent that biotechnology can be considered the world’s second oldest profession. Humans first used microorganisms empirically, without really knowing what was responsible for processes such as the production of bread, wine, and beer, which dates back to biblical times. Currently as a consequence of advances in molecular biology, along with a better understanding of nucleic acids and enzymes, microorganisms have become the main tool for genetic engineering - the basis of modern biotechnology - since they constitute the best known source of genetic novelty, in addition to their versatility, simple genetics, and ease of use (Berraquero, 2006).

It is widely accepted that the potential applications of microorganisms through biotechnology offer immense benefits in medicine, food production and other fields. Recombinant DNA technique has been the key to developing improved varieties of plants. The genome modifications made possible by this process has made the modifications of plants virtually limitless. Instead of confining breeding to varieties within one species, plant reproduction can now be expanded to combining plant DNA with that of other species of plants, animals and bacteria.

The types of potential hazards posed by GMOs vary according to the type of organism being modified and its intended application. Most of the concern surrounding GMOs relates to their potential for negative effects on the environment and human health. There are several types of potential health effects that could result from the insertion of a novel gene into an organism. Health effects of primary concern to safety assessors are production of new allergens, increased toxicity, decreased nutrition and antibiotic resistance (Bernstein et al., 2003). There is concern that inserting an exotic gene into a plant could cause it to produce toxins at higher levels that could be dangerous to humans. This could happen through the process of inserting the gene into the plant. If other genes in the plant become damaged during the insertion process it could cause the plant to alter its production of toxins. Alternatively, the new gene could interfere with a metabolic pathway causing a stressed plant to produce more toxins in response. Although these effects have not been observed in GM plants, they have been observed through conventional breeding methods thereby creating a safety concern for GM plants.

Despite many reassuring words by companies, researchers and some governments, many concerns about the implications of GM crops remain. Major concerns relate to the consequences for the ecological systems into which they are being introduced. For instance, the insertion of Bt (*Bacillus thuringiensis*) genes was thought to be a silver bullet, a permanent solution to insect problems. But the model of "one-pest-one solution" does not work forever, as is the case with pesticides; sooner or later resistance builds up. Similarly, building of herbicide resistance in plants is headed for trouble as it unleashes basic ecological reactions. Excessive use of herbicides as a major or only tool of weed management will eventually reduce the sensitivity of weeds to herbicides and create an even worse weed problem. It is "to a large extent a victim of its own success". Yield decline in GM soybean, for instance, is being traced to reduced root development, nodulation and nitrogen fixation. Another effect is related to the unexpected impact of gene transferred and its consequences. One example from USA tells how genes from one bacterium, *Xanthomonas* were transferred to another soil bacterium, *Klebsiella planticola*. The new organism was meant to ferment stubble into alcohol, thus providing farmers with an extra source of income instead of burning the stubble. However, a test by the authorities found that wheat planted in the soil containing the new organism was killed by it (LEISA, 2001).

One thing that makes the development of GE unique in the history of agriculture is that it is almost fully controlled by private companies. It appears that GE technologies are not being developed because of their problem-solving capacity, but because of the patent and thus profit it can bring to the companies. For instance, in the 1980s, Monsanto was not interested in genetically engineering virus resistance into plants, as it would bring minimal profits. Terminator gene technology takes the issue further. This technology, in which genes are manipulated to be able to switch seeds on and off by treatment with chemicals provided by one and the same GM Seed Company, effectively prevents farmers from keeping their seeds for replanting. Strong public opposition has forced the companies to give up this line of research, but they still hold the patents to the technology. The question is: do we really need GM technology to combat malnutrition, to improve local production and to make agriculture more productive. Has the introduction of GM crops contributed to the reduction of poverty? The FAO (United Nations Food and Agricultural Organization), in a recent report, indicated that "for the world as a whole there is enough, or more than enough food production potential to meet the growth of effective demand, that is the demand for food of those who can afford to pay farmers to produce it". The underlying factor is the purchasing power in the developing countries of the world. A wealth of agro-ecological, low-external-input alternatives to agricultural production is far from exhausted.

The case of natural crop protection indicates that there are many plants in nature which can provide us with clues for better disease and pest management. Many ecological principles that are still being overlooked, underestimated or sidelined deserve more attention as they provide relatively cheap, controllable and low external input solutions to many problems that farmers face. Moreover, these approaches are not accompanied by the many risks - both economic and ecological - that GM crops may be posing. In agriculture, the fight against harmful organisms is essential, and it is therefore necessary to develop appropriate technologies to regulate and control pests. One of the justifications for the development of GM crops is to build-in resistance to insects and diseases, which in turn is expected to reduce the negative impact of agrochemicals on health and the environment. Environmentally-friendly biological options that do not make use of genetic modification do exist. These options are based on natural crop protection approaches that make use of the diversity found in nature itself, providing excellent and competitive alternatives for pest management. The challenge in natural crop protection is to have simple and low-cost technologies that are able to regulate pests and diseases and to reduce or completely avoid the problem of contamination by agrochemicals. One such natural crop protection approach is based on the use of plants with biological control properties (Ubalua and Oti, 2008).

ETHICS AND CONTROVERSIES

Biotechnology is more than just a scientific issue. It is capable of engendering disagreement and controversy, and highlighting moral and ethical concerns which are difficult to resolve. These concerns include or arise from uneasiness over the fact that biotechnology is seen by some to "interfere with the workings of nature and creation", and that it might involve risk-taking for commercial profit. However, in priority setting, all concerns must be clearly balanced, respecting ethical aspects but reflecting the actual and potential possibilities of increasing food supplies and alleviating hunger. Robinson, (Robinson, 1999), reported that transgenic crops are about values, which are neither absolute nor universal, and that the controversies to a large extent have polarized society into proponents and opponents, with once seemingly trustworthy and ethically sound scientists being viewed with suspicion by many. He further stated that much of the argument is emotive, with talk of "cashing in on hunger", "Demon seeds", "Terminator Technology" and "Frankenstein Foods", and that it is difficult for anyone to appreciate any underlying truths, should they even exist.

Unarguably farmers have been accidental plant breeders for over ten thousand years, altering the genetic integrity of most crops without any knowledge of heredity. Jones, (Jones, 1994), was of the opinion that farmers were the first genetic engineers, although genetics as such did not come into existence until the work of

Mendel was rediscovered by de Vries et al. (1990). For instance, in traditional breeding techniques, breeders mix thousands of genes when crossing two plants in order to transfer the protein products to enhance one or a few genetic traits. But Charles Darwin once made the following comment on traditional breeding that: “the key is man’s power of accumulative selection, nature gives successive variations; man adds them up in certain directions useful to him”. Therefore, the odds of naturally occurring toxin being transferred unintentionally are far greater in traditional breeding than in biotechnology. To avoid toxicity, breeders spend many years backcrossing the new plant varieties with distant relatives. Backcrossing involves crossing new plant varieties repeatedly with plants whose genetic components are well known. This slowly dilutes the impact of all those unwanted genetic traits that came along with the few beneficial traits. Plant breeding is generally safe, but biotechnology can make it safer. Biotechnology brings to traditional plant breeding the ability to move single genes instead of having to move thousands and makes possible the identification of these genes and their products that are toxins.

The moral and ethical concerns are important factors in influencing a risk-averse public (Callahan, 1996), and are a pivotal feature of the debate on transgenic crops and their products (Newton et al., 1999). The basic questions which require answers are, do transgenic crops represent the solution to world hunger, and do they pose unacceptable risks to the environment and to human health? Obviously, science has had an enormous impact on human existence, providing numerous innovations which have improved the lives of many, and scientists have been regarded as trustworthy and ethically sound, and agricultural research and its role in food production as being intrinsically good (Hardon, 1997). This view has been altered somewhat by the advent of genetic engineering (GE), although it is generally appreciated that new technologies by their very nature represents a challenge to existing values and systems, and stimulate change in traditional concepts of nature and human identity (Carr and Levidow, 1997).

The effects of transgene escape on the environment are uncertain, but modern technology could limit such “genetic pollution” through, in some cases, engineering sterility into the transgenics to ensure vastly reduced gene flow into the farming and natural environments. Crops do not generally survive outside the farming environment and transgenic crops would probably be outcompeted should they spread off farm. According to Holmes, (1997), there is already evidence that many targeted pest species have developed resistance genes. This is a demonstration that nature fights back against the genetic engineer in much the same way as it fights back against the conventional plant breeder and many solutions to pest and disease problems represented by GE are likely to be short-lived. Furthermore, agrochemical control of crop pests is however inefficient and environmentally and ethically unsound and GE could offer a remedy, allowing more precise targeting of pest management (Pimentel, 1995). Proponents of biotechnology are of the opinion, that if genes from any of the most common allergens (milk, eggs, wheat, fish, shellfish, tree nuts (that is, walnuts), and legumes (that is, soybeans) are added to a food via biotechnology, a company has to either demonstrate through scientific data that an allergen is not present in the new food, or label the products to alert allergic consumers. The label must state that a potential allergen has been added to the food, but not that the food was produced via biotechnology. When developing plants through biotechnology, scientists use selectable marker genes to determine whether gene transfer has been successful, and have in the past used antibiotic proteins. The food and Drug Administration (FDA) has reviewed the use of selectable marker genes, and confirmed the safety of antibiotic-resistance marker genes and their rare use in biotechnology. Again in EPA, (1996) approved the use of *Bacillus thuringiensis* (Bt) in corn. Bt is a naturally occurring bacterium present in soil and known for its ability to control pests. Although harmless to most insects, people, birds, and other animals, Bt produces a protein that disrupts the digestive system of target insects.

Weil, (1996) believes that the effects of transgenics on the environment are controversial because of the great difficulty in gauging the associated risks. He argues that all actions are potentially hazardous, and that there have been no problems involving transgenics to compare with those that have been encountered previously as a result of classical plant breeding (e.g. Tcytoplasm and Southern corn leaf blight in the USA in the early 1970’s). Moreover, the hazards certainly do not approach the scale of environmental damage wrecked by disasters in traditional industry; the oil spill from the Exxon Valdez (Ubalua and Ezeronye, 2007) and the escape of radioactive fallout from the Chernobyl nuclear power station. Interestingly, while there is a public preoccupation with the potential hazards arising from genetically modified (GM) crops, environmental concerns about conventional crops are few (Annon, 1989a). Concar and Coghlan, (1999)], argued that an oilseed rape variety has been bred in Canada which carries genes for resistance to two herbicides using conventional means rather than through genetic engineering. Arguing further, Ort, (1997), mentioned several crops, including triticale, with its genomes from wheat and rye, which have contained “foreign” genes for a long time without occasioning any public outrage, or indeed causing any environmental damage. It is an immutable fact that human health already suffers as a consequence of agricultural practices. Farmers recognize more than anyone that healthy growing environments define their future.

Thus, they always seek better ways to control weeds with the least toxic herbicides available that do not damage crops. Farmers also would like to reduce their use of insecticides and fungicides, limiting their own exposure to the chemicals. Biotechnology can achieve many of these goals often more efficiently.

The ethical stand of some opponents of biotechnology was reviewed by Robinson, (1999) in which he addressed the position championed by Prince Charles, who claimed that GE takes mankind “into realms that belongs to God and God alone”. The implication is that the fate of humankind is in God’s hands and that our meddling nature is sinful and goes against his wishes. The question then is: where does divine responsibilities end and that of man begin? The dividing line is not clear, and all human endeavours could be said to interfere with God’s will to some extent. Words and terms are probably the root of problems associated with GE. But it should be borne in mind that classification is a man made concept. According to Robinson, (1999), creationist theory views life forms as being fixed and immutable, determined by God, whereas evolutionary theory is based on dynamic concepts and gradualism, whereby small changes (mutations) take place over extended times and the forces of natural selection results in the creation of new species. From all indications, it appears that opinions on transgenic crops are based on value judgments and possible negative health and environmental implications, and such values and attributes are likely to change with time and circumstance and with modifications to conceptual systems.

PROSPECTS

Genetic engineering has opened new avenues to modify crops, and provided new solutions to solve specific needs. The powerful combination of genetic engineering and conventional breeding programmes permits useful traits encoded by transgenes to be introduced into commercial crops within an economically viable time frame. There is great potential for genetic manipulation of crops to enhance productivity through increasing resistance to diseases, pests and environmental stress and by qualitatively changing the seed composition. Plant ‘factories’ are also being designed for high volume production of pharmaceuticals, nutraceuticals and other beneficial chemicals ((Hansen and Wright, (1999). Transgenic plants might become drug-delivery devices, with both HIV and rabies vaccines being synthesized in plants (Yusibov, 1997), and bananas have been engineered to produce edible vaccines. Moreover, with the establishment and expansion of genomics programmes, a much broader range of genes with potential for crop improvement are being identified and, in some cases, tailored and/or re-designed for further enhancement of their properties within specific crops (Estruch, 1997).

Plant transformation remains an art because of the unique culture conditions required for each crop species. Beyond crop improvement, the ability to engineer transgenic plants is also a powerful and informative means for studying gene function and the regulation of physiological and developmental processes. Transgenic plants are being used as an assay system for the modification of endogenous metabolism or gene inactivation. Advances in tissue culture, combined with improvements in transformation technology, have resulted in increased transformation efficiences. In recent years, many crops, previously classified as recalcitrant because they were stubbornly resistant to the overtures of genetic engineering, have now been transformed. Transformation technologies have advanced to the point of commercial-lization of transgenic crops. The introduction of transgenic varieties in the market is a multi-step process that begins with registration of the new varieties, followed by field trials and ultimately delivery of the seed to the farmer. Technical improvements that have the greatest opportunities for new approaches, probably in the realm of in planta transformation, will further increase transformation efficiency, extend transformation to elite commercial germplasm and lower transgenic production costs, ultimately leading to lower costs for the consumer (Hansen and Wright, 1999)

Conclusion

Genetic engineering (GE) is the most recent of a variety of ‘new’ technologies allowing plant breeders to produce plants with new gene combinations while recombinant DNA technology is in many ways an extension of the natural process of adaptation. Transgenic plants can assemble and accumulate many valuable proteins that can be economically extracted or processed. They often show advantages over other expression systems as factories for the production of pharmaceutical and Industrial proteins. Recent results of clinical trials on transgenic plant-derived pharmaceuticals are promising but the possibility of oral tolerance to plant vaccines remains a potential problem in need of further research. The prospects of agricultural biotechnology are obvious notwithstanding the controversies that it is generating especially in Europe. According to Brookes and Barfoot, (2005), there have been substantial economic benefits at the farm level, amounting to a cumulative total of $27 billion. GM technology has also resulted in 172 million kg less pesticide use by growers and a 14% reduction in the environmental footprint associated with pesticide use. GM crops have also made a significant contribution to reducing greenhouse gas emission by over 10 billion kg, equivalent to removing five million cars from the roads for a year (Conner et al., 2003). More work is needed to clarify the relevance of measurements in terms of the environment and soil-microbial, GM interactions.

Opinions are divided on the advantages and disadvantages of transgenic crops. The perceived advantages and disadvantages must be married to each other to provide a crop that is environmentally sound and non-hazardous. Producers of transgenic crops and the agencies that study their effects are aware of this fact. While the debates and campaigns on its adoption or not rages on, one may be inclined to believe that the technology is irreversible considering its spread and benefits so far. Public unease remains strong despite reassurances from scientists, and this may be because GE raises complex philosophical questions about the changing nature of agriculture. Media coverage, and a diminished public trust in regulatory authorities, may explain why GM crops have met rancorous public resistance in Europe. It is only time that will prove us wrong or right. It is obviously too late to keep the genie in its bottle and transgenic crops have been produced in abundance, being that we are in a period of extraordinarily rapid change in modern biology, but modern biotechnology may not diminish the need for conventional agricultural research. However, GE in fairness is not set to replace plant breeding, rather it represents a modern tool for use by the plant breeders, but the truth on the safety of transgenics hinges on reliable communication of information from scientists, policy makers, industry and the press. Whatever the scientific merits of the argument on the safety of GM foods, it is a fact that the “perceived” dangers of trans-genic crops are preventing their widespread adoption, particularly in Europe. Even in countries where the growth of such crops is not seen as a major issue (like the USA), the effect is still felt as export markets for food stuffs derived from genetically engineered crops are affected. Hopefully, with the emergence and future perfection of clean-gene technology, hopes are high that genetically modified crops may become acceptable to all, thereby resting the sceptisms and the fear that have polarized the proponents and the opponents of genetically modified foods.

REFERENCES

Alhassan WS (2002). Agrobiotechnology application in West and Central Africa (Survey outcome). Ibadan: International Institute of Tropical Agriculture. Ibadan, Nigeria.

Annon A (1989). Summaries of Country Reports, May 1989, World Bank-ISNAR-AIDAB-ACIAR, Biotechnology Study Project Papers. ISNAR, The Hague.

Berraquero RF (2006). Microbes and Society”, Contributions to Science”, Institut d’Estudis Catalans, Barcelona 3(2): 197-202.

Bernstein JA, Bernstein IL, Bucchini L, Goldman LR, Lehrer S, Rubin CH, Sampson HA (2003). Clinical and Laboratory investigation of allergy to genetically modified foods. Environ. Hlth. Perspectives. 111(8): 1114-1121.

Bridges A, Kimberly R, Magin M, Stave JW (2003). Agricultural Biotechnology (GMO). Methods of Analysis, In: Food Analysis. 3rd Edition. KLuvwer Academic/Plenum publishers, New York pp.301-311.

Brookes G, Barfoot P (2005). GM Crops: The global economic and environmental impact-The first nine years, 1996-2004. AgBioForum 8(2&3): 187-196.

Callahan D (1996). Biotechnology and Ethics: A blue print for the future. Keynote: Setting and communicating the limits in biotechnology. http://www.biotech.nwu.edu/nsf/callahan.html.

Carr S, Levidow L (1997). How biotechnology separates ethics from risks, Outlook on Agriculture 26: 145-150.

Concar D, Coghlan A (1999). A question of breeding. New Scientist pp. 4-5.

Conner AJ, Glare TR, Nap J (2003). The release of genetically modified crops into the environment. Part1. Overview of current status and regulations. Plant J. (33)1: 1-18.

CSA (Crops, Soils Agronomy) News (2007). A mixed Outlook for Pharmaceutical crops. www.crops.org

Daniell H, Muthukumar B, Lee SB (2001). Marker free transgenic plants: Engineering the chloroplast genome without the use of antibiotic selection. Curr. Gene. 37: 109-116.

DellaPenna D (2001). Plant metabolic engineering. Plant Physiol. 125: 160-163.

de Vries H (1990). The law of separation of characters in crosses. J. R. Hortic. Soc. 1901(25): 243-248

Dunfield KE, Germida JJ. (2004). Impact of genetically modified crops on soil and plant-associated microbial communities. J. Environ. Qual. 33: 806-815.

Dixon RA (2001). Natural products and plant disease resistance. Nat. 411: 843-847

Eastham K, Sweet J (2002). Genetically modified organisms (GMOs): The significance of gene flow through pollen transfer. Environ. Issue Report. 28 [Online]. Available at http://reports.eea.eu.int/environmental_issue_report_2002_28/en. European Environmental Agency, Copenhagen.

Elbehri A (2005). Biopharming and the food system: Examining the potential benefits and Risks. AgBioForum 8: 18-25.

Environmental Protection Agency (EPA), (1996). http://www.epa.gov.

Estruch JJ (1997). Transgenic plants: an emerging approach to pest control. Nat. Biotechnol. 15: 137-141.

Facchini PJ (2001). Alkaloid biosynthesis in plants: biochemistry, cell biology, molecular regulation, and metabolic engineering applications. Ann. Rev. Plant Physiol. Plant Mol. Biol. 52: 29-66

FAO (2000). Safety aspects of genetically modified food of plant origin. Report of FAO. Expert Consultation on Foods Derived from Biotechnology.

Fischer R, Stoger E, Schillberg S (2004). Plant-based production of Biopharmaceuticals. Current Opinion in Plant Biol. 7: 152-158.

Fraley RT (1991). Genetic Engineering in Crop Agriculture, Commissioned background paper prepared for the office of Technology Assessment.

Gebhard F, Smalla R (1999). Monitoring field releases of genetically modified sugar beets for persistence of transgenic plant DNA and horizontal gene transfer. FEMS Microbiol. Ecol. 28: 261-271.

Giddings G, Allison G, Brooks D (2000). Transgenic plants as factories for Biopharmaceuticals. Nat. Biotechnol. 18: 1151-1155.

Hardon JJ (1997). Ethical issues in plant breeding, biotechnology and conservation. pp. 43-50 In, Ethics and Equity in conservation and use of genetic resources for sustainable food security. Proceedings of a workshop to develop guidelines for the CGIAR, 21-25 April, Foz do Iguacu, Brazil, IPGRI.

Harlander S (1991). Biotechnology in Food Processing in the 1990s, commissioned background paper prepared for the office of Technology Assessment.

Hansen G, Wright MS (1999). Recent advances in the transformation of plants. Trends Plant Sci. 4(6).

Holmes B (1997). Caterpillar’s revenge. New Scientist p. 7

Horn EM, Woodward LS, Howard JA (2004). Plant molecular farming. Systems and products. Plant Cell Reproduction. 22: 711-720.

Kass J (2005). Commercialization of transgenic animals: Potential ecological risks. BioSci. 58: 46-58.

Jamie P (2005). Transgenic Animals: How genetics is providing new ways to envision agriculture. Biodiversity-Transgenic animals. http://www.biotech.ubc.ca/biodiversity/transgenicanimals/index.htm.

Jones S (1994). The language of the genes. Flamingo, London, 347p.

LEISA magazine (Magazine of low External Input and Sustainable Agriculture) (2001). GE-not the only option. 17(4): 4.
Ma K-CJ, Drake PMW, Christou P (2003). The production of recombinant pharmaceutical proteins in plants. Nat. Rev. Gene. 4: 794-805.
Ma K-CJ, Barros E, Bock R (2005). Molecular farming for new drugs and Vaccines. EMBO Report 6: 593-599.
Newton P, Brown D, Clover C (1999). Alarm over 'Frankenstein' foods. Electronic Telegraph. (1358) http://www.telegraph.co.uk.
Nielsen KM, Van EJD, Smalla K (2001). Dynamics, horizontal transfer and selection of novel DNA in bacterial populations in the phytosphere of transgenic plants. Ann. Microbiol. 51: 79-94.
Oger P, Petite A, Dessaux Y (1997).Genetically engineered plants producing opines alter their biological environment. Nat. Biotechnol. 15: 369-372.
Ort DR (1997). Pros and cons of foreign genes in crops. Nat. 385: 290
Paget E, Lebrun M, Freyssinet G, Simonet P (1998). The fate of recombinant plant DNA in soil. Eur. J. soil Biol. 34: 81-88.
Pimentel D (1995). Amounts of pesticides reaching target hosts: environmental impacts and ethics. J. Agric. Environ. Ethics 8: 17-29
Riba G, Dattee Y, Couteaudier Y (2000). Les plantes transgeniques et l'environnement. C. R. Acad. Agric. Fr. 86 : 57-65.
Robinson J (1999). Ethics and Transgenic crops: A review. Universidad Catolica de Valparaiso. Electr. J. Biotechnol. Chile. 2(2): 1-16.
Sala F, Rigano MM, Barbante A (2003). Vaccine antigen production in transgenic plants: Strategies, gene constructs and perspectives. Vaccine 21: 803- 808.
Ubalua AO, Ezeronye OU (2007) Determination and Assessment of heavy metal content in fish and shellfish in Aba River, Abia State, Nigeria. KMITL Sci. Technol. J. 7(1): 16-23.
Ubalua AO (2007). Cassava Wastes: Treatment options and value addition alternatives. Afr. J. Biotechnol. 6(18): 2065-2073.
Ubalua AO, Oti E (2008). Evaluation of antimicrobial properties of some medicinal plants for fresh cassava roots preservation. Pakistan J. Nutr. 7(5): 679-681.
Vandekerckhove J (1989). Encephalins produced in transgenic plants using modified 2s seed storage proteins. Biotechnol. 7: 929-936.
Verpoorte R, van der HR, Memelink J, (2000). Engineering the plant cell factory for secondary metabolite production. Transgenic Res. 9: 323-343.
Verpoorte R, Memelink J. (2002). Engineering secondary metabolite production in plants. Curr. Opin. Biotechnol. 13: 181-187.
Weil V (1996). Biotechnology and Ethics: a blue print for the future. Biotechnology: Social impact and quandaries. http://www.biotech.nwu.edu/nsf/weil.html.
Widmer F, Siedler RJ, Donegan KK, Reed GL (1997). Quantification of transgenic plant marker gene persistence in the field. Mole. Ecol. 6: 1-7.
Wolfenbarger LL, Phifer PR (2000). The ecological risks and benefits of genetically engineered plants. Washington DC. Sci. 3: 2088-2093.
Yusibov V (1997). Antigens produced in plants by infection with chimeric plant viruses immunize against rabies virus and HIV-1. Proc. Natl. Acad. Sc. U.S.A 94: 5784-5788.