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Transgenic cereals as vehicles for applied research and the political dimension of transgenic crops

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SUMMARY – Transgenic plants are now an integral part of contemporary agriculture. Globally over 90 million ha of transgenic crops were grown in twenty-one countries during 2005. Double-digit percentage increases in annual adoption rates have been recorded every year since the commercialisation of the first transgenic crops in 1996. The development and commercialization of transgenic plants is tightly linked with world trade, globalization, food security, environmental and consumer protection and intellectual property. In this article, we discuss the recent advances and current trends in transgenic crop development and their deployment. We also address some of the non-scientific issues that need to be resolved before these crops can realize their full potential in order to deliver a more sustainable and environmentally friendly agriculture. Finally we will highlight the importance of transgenic crops in contributing towards food security and poverty alleviation in the developing world.

Introduction

Crop improvement can be viewed as a continuum that was initiated millennia ago when humans first domesticated, selected and cultivated plants. It progressed through the use of: (i) animal power to make agricultural practices more efficient; (ii) Mendelian genetics that has put conventional plant breeding on a scientific footing; (iii) machines during and after the industrial revolution; (iv) chemical mutagens and ionizing radiation to create novel (useful) variability in existing germplasm; and (v) chemical assistance during the Green Revolution in the form of fertilizers and crop protection chemicals and finally, plant biotechnology. The interesting thing about plant biotechnology and the use of transgenic plants in modern agriculture, is that crop improvement can now be accomplished a lot more efficiently and quickly, often eliminating expensive and environmentally harmful practices and chemical inputs from the agricultural production chain. Because of the enormous potential of transgenic plants to revolutionise agriculture, the science and technology of the process has been tightly linked with issues of world trade, protectionism, globalisation, food security and intellectual property. It has played into the hands of dubious so-called "environmental" organisations that have their own agendas in trying to block this technology from reaching people, like poor subsistence farmers in the developing world, who need its benefits the most.

Historical background

Plant genetic modification requires efficient and facile gene transfer methods that will be generally applicable to as many plant species and genotypes as possible (Christou *et al.*, 1991). This is important once we move from model laboratory plant species such as *Arabidopsis thaliana* and *Nicotiana tabaccum*, to the cultivated crops. Divergence in the molecular mechanisms through which different plants express transgenes, make it necessary to design appropriate genetic constructs with different promoter elements, introns or enhancers, for example in monocotyledonous *vs* dicotyledonous plants. The delivery and stable integration of foreign genes into plant cells is the first step towards the creation of transgenic plants (Christou, 1996). Once foreign genes are integrated into the host genome, they need to be translated and transcribed. The resulting gene products, e.g. proteins, enzymes, hormones, etc., need to be stably expressed over subsequent generations. Investigations of mechanisms and factors that influence proper transgene expression have been the subject of intense study (Kohli *et al.*, 2006). Such studies focusing on transgene silencing have resulted in the development of highly sophisticated models that attempt to provide a rational basis for the occasional, aberrant expression of transgenes that are integrated into the plant genome. In turn, such experiments form the basis of improved strategies for creating transgenic plants that stably express the introduced transgenes. Additional factors that contribute to transgene expression stability (or instability), are being investigated and such studies are now beginning to reveal the importance of how a transgenic locus is organised following gene transfer (Kohli *et al.*, 2003).

Current trends in transgenic crop development

The development of transgenic technology continues to expand into increasing numbers of crops and introduced traits (James, 2005). The focus remains on the major field crops of soybean, maize, cotton, oilseed rape, rice and potato with introduced genes conferring herbicide tolerance and/or pest resistance. Second and third generation transgenic plants encompass plants that are currently in the production, or research and development pipelines and are expected to reach commercialization in the next five to ten years (AGBIOS, 2006). In addition to "stacked traits" combining insect resistance and herbicide tolerance in the same crop, further traits include food quality and nutritional enhancement (e.g. plants with increased levels of bioavailable iron and enhanced vitamin content); productivity increases through the manipulation of physiological (e.g. photosynthetic rate and improved nitrogen uptake) and biochemical (e.g. plants with altered metabolic profiles for non-food applications) characters; tolerances to abiotic stress (e.g. plants that are better able to survive and proliferate under extreme environmental conditions or on marginal soils); development of plants for the production of pharmaceuticals for human and veterinary applications; and plants that contribute to environmentally friendly agriculture and sustainability, are to name a few. Ultimately we are looking at the development of crop plants with enhanced yield potential, better adaptability to water and nutrient uptake, leading to more sustainable and environmentally less-damaging agriculture. Food security issues, in particular within the Southern hemisphere, concern many plant biotechnologists and policy makers and this is an area where major, positive impacts of second- and third-generation transgenic crops are beginning to bear fruit, and are expected to contribute even more substantially.

Political dimension, impact and regulation

In an ideal world, everyone would have secure access to an adequate supply of safe and nutritious food. This is something that western societies take for granted, given the seemingly unlimited quantity and variety of fresh produce available on supermarket shelves. In the developing world, however, 840 million people are chronically undernourished, surviving on fewer than 2000 calories per day (Pinstrup-Andersen *et al.*, 1999). Many more people, perhaps half of the world's population in total, suffer from diseases caused by dietary deficiencies and inadequate supplies of vitamins and minerals. It is not therefore surprising that contemporary plant biotechnology stands to benefit huge numbers of people in the developing world, to a much greater extent than consumers in the affluent west. Perhaps this is one of the reasons why well-fed Europeans, who enjoy very high living standards and quality of life, can afford to reject in the short term, technologies on the basis of ideology and vested economic and political interests.

All transgenic plants are required to undergo thorough and rigorous safety and risk assessment before commercialisation. Regulation, amongst other things, is an important component of transgenic crop development and field deployment as it provides *de facto* assurance to the public that all products approved for commercial release, are at least as safe as their non-transgenic counterparts (Ramessar *et al.*, 2007).

Intellectual property issues (IPR)

Most countries have legally established that it is reasonable for an inventor to be given a monopoly, or the right to exclude others from the sale or use of an invention for a limited time, in return for a full public disclosure of how the invention is performed. In economic terms this right of exclusivity is important because it allows the inventor to recover the research investment while not giving competitors free access to the newly created intellectual knowledge (Sechley and Schroeder, 2002). That being said, the public disclosure of the invention allows competitors to improve upon, or work around the patent. Intellectual Property Rights are covered by an international treaty: Trade-

Related Aspects of Intellectual Property Rights (TRIPS). The treaty obliges member states to protect through patents inventions on any product or process, in any field of technology, assuming such inventions are novel, non-obvious and useful, i.e. capable of commercial exploitation. TRIPS provide grounds for exclusion in granting patent protection on moral, ethical and other grounds. Such exclusions are non-uniform across different territories and this causes great confusion in applying the terms of the treaty. A number of different vehicles exist for protecting plant-related inventions: plant variety protection, US plant patents and utility patents. The process of creating a transgenic plant is a multi-component enterprise and very often, each individual component might be the subject of IP protection. Claims may be directed towards explants used for transformation, the vectors and genetic constructs, transformation procedures, and selectable and/or screenable markers. Early plant biotechnology patents provided inventors with very broad claim protection. However, a number of these early patents have been challenged in court and some have been overturned. It is now becoming increasingly difficult to obtain a patent with a broad scope of claims.

An issue that is pertinent to IP protection concerns plants and other biotechnology products or processes for humanitarian use, specifically for developing country applications. Precedence exists for at least two examples which pave the way for making IP protection and humanitarian use compatible. One example is "Golden Rice", a variety of rice engineered with the vitamin A pathway genes that accumulates beta carotene. The creators of this rice strain were able to convince all IP holders to donate all relevant IP to allow freedom to operate (FTO) for developing countries. The consequence of this agreement is that there are no IP constraints on "Golden Rice" and therefore, this material can be freely distributed to the people who need it the most, i.e. people in the developing world who are deficient in vitamin A. The second example is provided by the Pharma-Planta EU project, a consortium of 39 different laboratories in Europe and South Africa working on plant-made pharmaceuticals, focussing on HIV/AIDS, tuberculosis, diabetes and rabies. All members of the project have signed a humanitarian statement which guarantees FTO for the products and the technology derived from the project, for humanitarian use in developing countries.

Concluding remarks

In industrialized countries, the key benefits of transgenic plants include more environmentally friendly and sustainable agricultural production practices obtained by limiting the number of chemical inputs that are required in conventional agriculture. Genetically enhanced crops have the potential to address some of the causes of hunger in the developing world, both directly (by increasing the availability of food) and indirectly (by reducing poverty in developing countries) (Fig. 1; Christou and Twyman, 2004). Crop failure due to pests and diseases, could be averted by the adoption of plants that are resistant to such biotic stresses. The development of plants that are tolerant of extreme environments could allow marginal soils to be brought into agricultural use, and could allow plants to survive periods of drought or flooding. The modification of plant architecture could increase yields and sturdiness by diverting biomass from stems and stalks, to the edible organs. Overall yields could be increased by manipulating photosynthesis, carbon and nitrogen metabolism or modifying plant development to promote early flowering, and multiple growth cycles per year. Exhausted soils could be sown with crops that are better able to extract nutrients, and contaminated soils could be regenerated by plants developed for bioremediation. These measures, in combination with conventional breeding and developments in other agricultural practices, may produce the estimated 50% increase in grain yields required over the next 50 years, to cope with the anticipated increase in the global population. Overwhelming evidence has demonstrated the benefits of early generation transgenic crops in terms of increased yields and reduced chemical inputs, despite claims of special interest groups that such early products did not provide any benefits to consumers (Toenniessen *et al.*, 2003; Huang *et al.*, 2005; Christou *et al.*, 2006). Knock-on effects include improved farmer and consumer health and a cleaner environment. The future security of food-supplies depends in part, on science providing the tools to allow efficient agricultural production, which is sustainable in every sense; furthermore, sustainability of food production has to be considered seriously and not be used as a political slogan by so called "concerned consumers" and environmental or political groups with hidden agendas. Transgenic plants have a twenty-three year track record of success and safety which will become progressively more difficult for opponents of genetic engineering technology, to ignore.

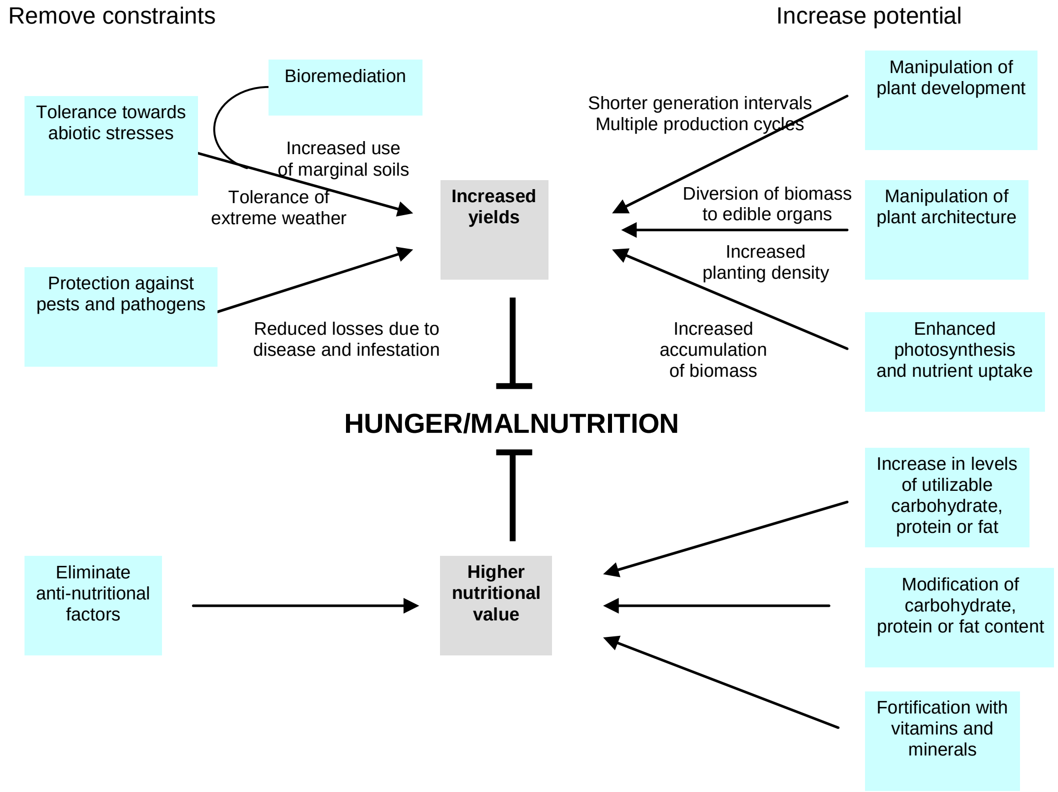

Fig. 1. Impact of transgenic plants on food security (Christou and Twyman, 2004).

Transgenic plant releases and commercialization are governed by Draconian rules unparalleled elsewhere in any other sector. The European Union in a report following a fifteen year study (1985-2000) involving 400 public research institutions, to the cost of 70 million Euros concluded "… *genetically modified plants and products derived from them present no risk to human health or the environment……these crops and products are even safer than plants and products generated through conventional processes*" (EC, 2001).

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