The Future Prospects of Fruit Biotechnology- An Indian Perspective

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Introduction

A recent report of the Food and Agriculture Organization entitled '*State of the World's Land and Water Resources for Food and Agriculture* (SOLAW)' warns us about the rampant degradation and continued shrinkage of land and water resources putting the key food production systems around the globe at risk. It also notes that world is facing a profound challenge to feed a world population expected to reach 9 billion people by 2050. About 25 percent of the earth's lands are degraded spanning soil and water resources and biodiversity (FAO, 2011). In addition, the global climate change endangers global food production (IPCC, 2007; FAO, 2011) and the developing countries are likely to bear the brunt of the problem (Rosenzweig and Parry, 1994). At this point, we have to explore and design the possible strategies which could stabilize food production under adverse agro-edaphic conditions and pest-disease pressure. The changing global food consumption trend, with emphasis on health protective fruits and vegetables, is also to be taken into account (Kearney, 2010). Being rich in vitamins, minerals and nutraceuticals, fruits are excellent health protective foods (Riboli and Norat, 2003). Here comes the real issue as how all sorts of fruit crops can suitably be grown under hostile conditions so as not only to productively utilize the available resources but also to meet the growing demand of nutritious food. One may argue that conventionally bred fruit cultivars would give desirable results when grown under improved management practices. This argument can be accepted in degree because conventional fruit breeding is constrained by many factors (Petri and Burgos, 2005; Checker *et al*., 2012) and the chances of developing superior types are meager, if not rare. Contrary to this, transgenesis and adjunct technologies such as marker-assisted breeding may prove crucial in the development of fruit ideotypes for diverse requirements. Keeping in check the biotic and abiotic stresses is the foundation of sustainable agriculture (Checker et al., 2012) and available literature is ample to prove that genetic engineering can be successfully employed to impart resistance to insect-pests (Dandekar *et al*., 1998; Tao *et al*., 1997), diseases (Faize *et al*., 2003; Ghorbel *et al*., 2000; Lius *et al*., 1997) and abiotic stresses (Cervera *et al*., 2000; Checker *et al*., 2012) affecting fruit crops. In addition, genetic transformation can be attempted for improving desirable horticultural traits such as precocity (Pena *et al*., 2001), rooting in cuttings (Welander *et al*., 1998), branching (Smigocki and Hammerschlag, 1991) and fruit quality (Costa *et al*., 2002). Success in developing higher quality fruits bringing tangible value to the consumer could improve the market acceptance of GM fruits (Clark *et al*., 2004). This is, however, only one side of the story. There are biological (Petri and Burgos, 2005), regulatory (IFPRI, 2007) and ideological (Herring, 2008) constraints in the commercialization of genetically transformed fruit cultivars. Here we

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attempt to identify the constraints which are creating stumbling blocks in the adoption of biotechnology related techniques in fruit crops with special reference to India.

Biological constraints

Genetic transformation holds the promise to revolutionize fruit industry by the development of varieties having specific traits through precise genetic manipulation, which seems unachievable through conventional breeding (Krishna and Singh, 2007). Nonetheless, there are well known constraints hampering the future of transgenic technology in fruit crops. In the first place, unlike annual field crops, genetic transformation is not a routine practice in fruit crops and most of the attempts in this direction are limited to a few genotypes. The development of genotype-independent protocols would prove decisive in the future of transgenic development in woody fruit species (Petri and Burgos, 2005). A sorry aspect of genetic transformation in fruit trees is that most of the works have focussed almost exclusively on enhancing insect-pest and disease resistance (Gambino and Gribaudo, 2012). Barring a few exceptions, reports on other aspects are missing. Moreover, owing to complex biology and time consuming field trials even the disease-resistant transgenic lines could not be commercialized (Gambino and Gribaudo, 2012). Another big issue is that of plants carrying antibiotic resistance genes. Development of protocols to avoid the use of antibiotic selection or to allow elimination of marker genes from the transformed plant will be a research priority in the future (Petri and Burgos, 2005). Removal of antibiotic resistance genes from transgenics eliminates the risk of their transfer to the environment (Iamtham and Day, 2000) and the non-transgenic plants (Petri and Burgos, 2005). In addition, such strategies are desirable which avoid *Agrobacterium* persistence in plant tissues (Dominguez *et al*., 2004). In perennial woody fruit species, which grow in the field over several decades, it is very important to evaluate the stability of transgene integration and expression over long periods of time for validating the potential and environmental-friendly nature of genetic transformation technology (Cervera et al., 2000; Pena and Seguin, 2001). The stable expression of trasgenes in the host genome greatly depends on its successful insertion and the proximity to appropriate host regulatory sequences (Flachowsky and Hanke, 2006). Unfortunately, little is known about these features in woody fruit crops (Cervera *et al*., 2000; Flachowsky and Hanke, 2006). A detailed screening of the transgenic citrus plants confirmed the stable integration of transgenes under natural environmental conditions (Cervera *et al*., 2000). Nonetheless, the time and money consuming screening process for validating the stable genetic transformation may itself pose a big challenge in resource poor countries. Parthenocarpy and male sterility have recently been examined as ways to prevent gene escape into environment (Flachowsky and Hanke, 2006) and these techniques have to be validated in different fruit crops for cost effective estimation of stable genetic transformation.

Regulatory constraints

Stringent regulatory issues and higher costs are limiting the commercial opportunities for the GM varieties in horticultural crops. Besides safety assessments, significant barriers in the way of new transgenic varieties in horticultural crops include the huge costs of varietal development, regulatory approval, post-commercialization initiatives and the reluctance of marketing industry to accept GM horticultural products (Redenbaugh and McHughen, 2004). Effective regulatory mechanism must be in place to ensure that transgenic traits are safe for both the consumers and the environment. However, such regulations should not prove insurmountable barriers to the commercialization of horticultural products that could bring significant benefits to the producers, consumers and the environment (Bradford *et al*., 2004). Science and politics are distinct activities. The scientific enquiry for regulatory requirements should not be subjective and partial. An objective scientific analysis must take into account the possible benefits of the adoption of a new transgenic variety (Raybould, 2012). The recent ban on the cultivation of transgenic MON810 maize in Germany and France has led to a debate about whether the bans were ‘‘scientifically justified’’ (Ricroch *et al*., 2010; Hilbeck *et al*., 2012). The continuous increase in acreage under GM crops worldwide is a pointer of the recognized benefits of reduced pesticide use and conservation tillage infusing sustainability to the agricultural ecosystems (Bradford *et al*., 2004). Among Asian countries, India took the lead to invest in agricultural biotechnology research and to set up a biosafety system to regulate the approval of genetically modified (GM) crops. Despite the Government of India’s acknowledged interest in encouraging growth in the biotechnology sector, the approval of new applications of transgenic crops has been rather slow. At the same time, an increasing number of government departments are getting involved in biosafety, marketing, and trade regulations. As a result, the Indian agribiotech sector is in a transition phase both in terms of research applications and the regulatory framework. Besides these hurdles, the high cost of biosafety regulation is proving an impediment to the commercialization of transgenic technology (IFPRI, 2007). To ensure safety to the consumers and the environment, extensive testing is required for the regulatory approval of GM crops. In field crops, testing costs can be reduced by citing the past data for the same traits. However, the costs could be millions of dollars for testing the novel traits in fruit crops (Clark *et al*., 2004).

The market and the grower

The commercial applications of biotechnology to horticultural crops lag far behind those of agronomic crops. In some respects this is to be expected, since the majority of research and investment has been directed to commodities with the greatest commercial value. For consumer and quality traits, however, many of the most interesting applications will be in horticultural crops. In fruit trees and vines, the variety selection is a long-term commitment and growers remain cautious in planting novel varieties. This fact may prove negative in the acceptance of the new GM fruit variety. Presently, the lack of market acceptance is seen as the biggest impediment in the adoption of GM horticultural products. In comparison to the staples such as rice and corn, the markets for the fruits are smaller and as such private players and MNCs have less interest in investing in fruit biotechnology (Clark *et al*., 2004).

Public opinion and ideological constraints

The social ethics and values, the cultural ethos and the role of electronic and print media are some factors which determine the acceptance of a given technology among the masses and it is equally applicable to the GM crops (Goyal and Gurtoo, 2011). Instead of accepted and significant contributions of genetic engineering in pharmaceutical industry, its progress remains sluggish in farming sector. The opposition of transgenic technology in food crops reminds us of a 'global cognitive divide' arising out of diverse interests and ideologies (Herring, 2008). In developed countries, a mixed public opinion is observed with respect to food biotechnology. In North America, for instance, consumers seem to be untroubled by the prospect of genetically modified fruits entering the food chain. The European consumers in general and those in Western Europe in particular reject the North American belief and there is skepticism about GM foods. In some European countries organized protests against genetically modified food have made a considerable impact (Durant, 1998). In a nutshell, Europeans and Japanese show a negative attitude whereas in the United States people are more receptive to GMOs. Surprisingly, in most developing countries genetic engineering is seen as necessary for the development of the nation given that people are not at risk (Goyal and Gurtoo, 2011). Contrary to other technologies, the opposition to the GM crops is of spiritual nature and it is argued that we should not be 'playing god' or 'tampering with nature' (Frewer and Shepherd, 1995). In India, food is a part of cultural and religious identity. There are issues concerning the use of genes derived from animals (Newell, 2003). In a developing society like ours, the media should be objective and the facts should be presented accurately with due focus on the scientific perspective. Media should not fall into the trap of flashy anti-GMO drives (Goyal and Gurtoo, 2011). The proponents of agricultural biotechnology use the 'principle of substantial equivalence' to justify their claim that there is no need to certify that GM foods are safe, just as there is no need to justify that natural foods are safe (Basu, 2006). However, care must be taken to ensure public health and safety. Unlike other foods, most of the fruits are consumed fresh and this has implications for perceptions of quality and food safety that may influence consumer acceptance (Alston, 2004). Surveys have revealed that consumers do not agree about whether GM foods are good or bad. Generally, stiff opposition comes from a small section of people. The point that majority of the consumers are uninformed about the transgenic technology and the GM food highlights the constructive role to be played by the media, research institutions and the government agencies to provide clear and objective free of any prejudice (James, 2004.).

Future prospects

The development and dissemination of new technologies is said to be a future strategy to solve the problems of poverty, malnutrition, hunger and diseases in the economically developing and underdeveloped nations. New generations of Euro-American development scientists are increasingly touring biotechnology as a panacea for the ills plaguing poor Asian, African and Latin American countries (Kenney and Buttel, 1985). The emerging frontier sciences such as biotechnology are seen as enabling technologies which, if meticulously tapped up, could open up window of opportunity for a less developed country (Niosi and Reid, 2007). The diffusion of modern biotechnology capabilities will assume great importance in near future for overcoming the problems of global as well local food crises in developing countries, which are likely to be accentuated by the global climate change (Evenson, 1999). It is argued that India should take a cue from the success of software revolution and there should now be concerted focus on capitalizing food biotechnology (Krishnan *et al*., 2003) which might usher in a second green revolution (Basu, 2006). It is noted that in order to fully harness the potentials of biotechnology for the benefit of poor producers and consumers in developing countries, the public sector has to develop innovative partnerships with the private sector for gaining access to the required research platforms (Byerlee, and Fischer, 2001). History tells us that agricultural development depends on effective technological interventions and technology will continue to play a crucial role in the future. Molecular biology is seen as the latest wave of technological change in agriculture. However, the future of this technology in horticultural crops faces many hurdles. In so far as fruit crops are concerned, heavy expenditure on research, development and regulatory approval and market barriers limit the profitable applications of biotechnology. When we talk of the cost involved, the application of genetic engineering in fruit trees is comparatively expensive owing to relatively larger experimental units and the time taken. Again, it will be costly to plant the orchards with a new GM variety. The present socio-political and market context has made the private players reluctant to invest in fruit biotechnology research (Alston, 2004).

The only fruit currently marketed (in the United States) is GM papaya resistant to the Papaya Ring Spot Virus (Clark *et al*., 2004). The developments such as increasing emphasis on the modification of genes of crucial importance for creating novel and useful traits, the advent of 'clean' transformation technology (without insertion of antibiotic resistance genes and non-plant sequences), publications of several fruit genomes and functional analysis of genes are proving conducive for fruit biotechnology (Gambino and Gribaudo, 2012). Genetic manipulation of ethylene biosynthesis has great potential for application in tropical fruits such as mango, papaya and banana which have poor shelf-life (Clark *et al*., 2004). Research is well under-way to build a robust platform of technologies to utilize genomics in the discovery of useful traits for trees (Dandekar *et al*., 2002). In addition to modification of ripening, projects to increase the content of vitamins, minerals or nutraceuticals in horticultural products are in progress (Grusak and Della Penna, 1999).

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