J. Indian bot. Soc. e-ISSN:2455-7218, ISSN:0019 - 4468 Vol. 101 (4) 2021: 254-268

IMPACT OF PLANT TISSUE CULTURE ON ADVANCES IN PLANT BIOLOGY

MOHAMMAD ANIS

(UGC-BSR Faculty Fellow), Plant Biotechnology Laboratory, Department of Botany, Aligarh Muslim University, Aligarh 202002 (India)
Email:anism1@rediffmail.com
Date of online publication: 31st December 2021
DOI: 10.5958/2455-7218.2021.00032.2

I wish to thank and express my sincere appreciation to the Executive Council and the members of the Indian Botanical Society for the great honor by electing me unanimously, the President of 43rd all India Botanical conference being organized at CSIR-National Botanical Research Institute, Lucknow during March 19-21, 2021. However, I am still of the opinion I do not deserve this singular honor to the extent several senior botanists of our country do.

Ladies and Gentlemen, I am proud to have been taught Botany at Post Graduate level by several illustrious teachers at the University of Lucknow, particularly Prof. S. S. Raghuvanshi, who guided me as a PhD scholar. I pay my homage to late supervisor and offer respectful regards to the surviving ones.

The Indian Botanical Society came into existence in 1920 with clear objectives to promote the cause of Botany in India in all its aspects and botanists have dedicated themselves to promote the growth of subject. Though they had their own specialization but were honestly and sincerely equally concerned with overall growth of botany. I am happy that my Presidentship has coincided with holding of this session in the city of Nawabs- Lucknow during the "Centenary Year 2020"

Since it is customary to speak on one's own contributions during an address, there were two options open to me: (i) to speak on Cytogenetics, my area of research where I earned my PhD degree or (ii) on the Plant Cell, Tissue and Organ culture, area of my current or final interest. I chose the later because it has a wider prospective in the present context and is suitable for a general gathering.

I am sure everyone is familiar with the work of Prof P. Maheshwari who initiated the work on tissue culture in 1950 in the Department of Botany, University of Delhi. Prof. Maheshwari has been one of the most outstanding personalities in Indian science and indeed in world of Botany. First major contribution of tissue culture to general Botany (to some extent general Biology) concerns totipotency i.e., demonstration of the fact that every cell has the potential of making an embryo and a plantlet and from which one insight emerged, i.e. differentiation which is basically a matter of programmed switching off and switching on of gene activity rather than total loss of genes. A second contribution of tissue culture relates to hormonal control of differentiation – more specifically, in showing the importance of auxin/cytokinin balance in controlling morphogenesis of roots and shoots. Differentiation has been achieved in many plants from group of cells or calli and the techniques have now begun to be applied to more difficult dicotyledonous plants such as legumes. In fact in monocots, such as maize: which were regarded as recalcitrant only the other day, have now been successfully cultured.

Biotechnology is aptly described as the

Presidential address delivered at the 43rd All India Botanical Conference held at CSIR-NBRI, Lucknow, and 19-21 March 2021

Received on August 16, 2021 www.indianbotsoc.org Accepted on August 18, 2021

"Technology of Hope" for its promise to deliver food security, life-saving drugs, alternate energy and environmental sustainability. Science and Technology feed on each other. Advances in basic Sciences contributing to newer technologies are well known. The emergence of newer technologies also leads to a renewed and a revitalized interest in the study of basic Sciences. No other example is more striking than the resurgence of interests in the study of Biology as a result of the birth of new Biotechnology, which has opened a flood gate. The barriers between Sciences are disappearing and even students of Physics, Mathematics and Chemistry have started looking at Biology with respect and bewilderment.

In conjunction with conventional technologies, modern biotechnology holds promise of increased and sustained productivity, efficient processing for improved product diversification and utilization, decreased reliance on agrochemicals and other external inputs and better conservation of genetic resources. Biotechnology as such is not new to society. Fermentation of beer, production of antibiotics and manufacture of cheese has been known for a long time. Plant breeders have been active for decades evolving newer strains for increased productivity and disease resistance but, an unprecedented opportunity to evolve new technologies presented it when it was shown that gene fragments can be lifted from one organism and introduced and propagated into another across barriers of sexed species. The gene of interest can not only be multiplied but can also be made to express the protein for which it has the sequence information. Thus, human growth hormone gene can be introduced into *E. coli* and the latter made to produce the hormone.

Genes have also been introduced into plant cells such that it acquires the ability to degrade specific pesticides. In another approach, the toxin gene from *Bacillus sphaericus*, producing a protein toxic to specific lepidopterans, has been cloned into plant cells which now make their own biocide. Gene cloning in plants cells poses its own problems. The Ti- plasmid is more or less the only vector used extensively and is not largely effective in monocots. Recently, direct DNA introduction methods such as electroporation and shooting with DNA coated tungsten bullets have given encouraging results. DNA has also been introduced directly into the germ tube and floral tillers to generate transgenic plants. There is every hope that gene technology can give rise to disease-resistant, pesticide-resistant and drought-resistant plants leading to increased productivity in quantitative and qualitative terms. Biotechnology does not comprise only genetic engineering or Recombinant DNA technology. There exists a gradient of biotechnologies varying in degree of sophistication, complexity stage of development, and most importantly application. At one end of the gradient, there are *in vitro* technologies, fermentation and bio-fertilizer technologies, and on the other end of the gradient, there are advanced technologies such as genetic engineering, molecular breeding and genomics. In the present communication, I would focus only on a few of the wide range of applications to illustrate the potential of agricultural biotechnology.

***In vitro* Technologies:** Plant cells can be successfully cultured in a well-defined medium and is comparatively a simpler proposition. Unlike the animal system, the whole plant can be generated by a combination of methods based on (a) Soma clonal variation, (b) Gene cloning, (c) Haploid culture, (d) Protoplast fusion, (e) Somatic embryogenesis, and (f) Micropropagation.

Successful regeneration through micropropagation or somatic embryogenesis has been achieved for about 100 forest species. However, considerable development work is required for commercial propagation of valuable forest tree species using in vitro techniques. Inclusion of a micro multiplication phase may facilitate more rapid development of superior genotypes than is afforded by sequential multiplication by culturing. In vitro manipulation of the maturation state (for instance, promotion of early flowering of tree species to reduce generation intervals), and in vitro selection for traits such as disease and insect pest resistance or a biotic stresses such as salinity, are some of the important applications of biotechnology with obvious value for forestry.

A laboratory of Plant Tissue Culture and Molecular Biology has been established in the Department of Botany, Aligarh Muslim University, Aligarh by me in 2001 for pursuing basic and applied research. The laboratory has been working on micropropagation, conservation and molecular characterization of some useful plants including medicinal, woody, ornamentals and agricultural crops such as *Mucuna pruriens* (Faisal *et al.* 2006), *Cardiospermum halicacabum* (Jahan and Anis 2009), *Solanum melongena* (Khan *et al.* 2009), *Pterocarpus marsupium* (Husain *et al.* 2010, *Tylophora indica* (Faisal and Anis 2010), *Balanites aegyptiaca* (Anis *et al.* 2010, Ahmad and Anis 2019, Varshney and Anis 2014*), Capsicum annuum* (Khan *et al*. 2011), *Nyctanthes arbor-tristis* (Jahan *et al.* 2011), *Vitex negundo* (Ahmad and Anis 2011), *Withania somnifera* (Fatima et al. 2011, 2013), *Salix tetrasperma* (Khan *et al.* 2011), *Albizia lebbeck* (Perveen *et al.* 2012; Perveen and Anis 2014), *Bauhinia tomentosa* (Naz *et al*. 2012), *Rauvolfia serpentina* (Faisal et al. 2012), *Tecomella undullata* (Varshney and Anis 2012), *Vitex trifolia* (Ahmed and Anis 2012, 2014), *Ocimum basilicum* (Shahzad *et al.* 2012), *Acacia ehrenbergiana* (Javed *et al.* 2013), *Cassia angustifolia* (Siddique *et al.* 2013), *Dianthus caryophyllus* (Varshney *et al.* 2013), *Cassia alata* (Ahmed and Anis 2014), *Syzygium cumini* (Naaz *et al.* 2014*), Cassia occidentalis* (Naz *et al.* 2015, 2016), *Erythrina variegata* (Javed and Anis 2015), *Althaea officinalis, Tecoma stans* (Hussain and Anis 2019, 2021).

A number of reproducible protocols have been devised using different morphogenic pathways on plants belonging to different categories for the conservation of Phytodiversity. Through *in vitro* techniques, genotypes can be cloned at a faster rate to achieve the requisite plant material in the shortest possible time as per need. The technique has been used globally not only for the *ex-situ* conservation of plants but also the monitoring of secondary metabolites at various stages of growth and differentiation (Anis and Ahmad,2016).Besides, plant tissue culture can also be used for the production of useful secondary metabolites (Khanam and Anis 2018) in *Allamanda cathartica*. Tissue culture methods have been used to produce adventitious somatic embryoids that can serve as "artificial seeds". These have been encapsulated in biodegradable gels resulting in the production of "syn-seeds" of uniform high quality. This obviates the necessity to generate plantlets by tissue culture method and then transfer them to field conditions.

Molecular marker technologies for crop improvement: Crop breeders and biologists now have an excellent opportunity to peer into the structure, content and dynamics of crop plants. Genome mapping using molecular markers is now extensively done in a number of crop plants including maize, rice, wheat, brassica, sorghum, barley, oat, pearl millet, tomato, sugarcane, pea etc. This information is helping researchers not only for localization of genes which are located in related crops.Besides facilitating unambiguous identification of ergonomically elite lines through DNA fingerprinting, molecular marker technologies are enabling scientist to distinguish between and compare species with remarkable precision. Knowledge of the genetic composition of the wild relatives of crop plants is aiding breeders to identify and make use of genes that encode traits that are beneficial for food production. The demonstration by a research team led by Professor Steve Tansley at Cornell University, USA, that the wild relatives of rice can be successfully utilized through molecular marker-assisted strategy to bring improvement in the yield potential of cultivated rice and this provides an excellent example of the power of the modern technology.

Comparative genome mapping of crop plants in general and cereals in particular resulted in significant findings about the conserved linearity of gene order. This observation is likely to accelerate the application of Quantitative Trait Loci (QTLs) in a variety of important crops like rice, wheat and maize, as well as aid in the identification of genes required for introgression from alien species. Given the low number of loci tagged at present in wheat and the problems related to developing a high-density map for wheat, the impact from this linearity on wheat improvement will indeed be significant. Attempts are being made worldwide to efficiently integrate molecular marker technology into existing plant breeding programs to allow researchers to access, transfer and combine genes at a rate and with a precision not previously possible. As breeders strive to increase the number and complexity of traits that must be incorporated into new cultivars, they have to develop appropriate identification and screening procedures. The simultaneous or sequential screening for multiple biotic and/or abiotic stresses may become impractical or even impossible using conventional procedures. The use of novel techniques like the DNA marker technology will help to identify genetic linkages to qualitative and even to complex inherited quantitative traits. If linkages are established, selection for several traits is possible in a short time with the aid of molecular markers. Molecular marker-assisted selection has already brought in a remarkable improvement in breeding for those traits controlled by one or few genes. There are some constraints to overcome for effective application of this technology for quantitatively inherited traits.

Genetic Transformation of Crop Plants: Genetically modified crops are developed through the process of genetic engineering by incorporating a foreign gene (or genes) to the crop species through procedures different from natural pollination or sexual reproduction. These are also known popularly as Genetically Modified Organisms (GMOs) or referred to as Living Modified Organisms (LMO) or transgenic organisms. A GM crop is produced principally by introducing a gene sourced from a foreign organism that does not naturally hybridize with the crop species being genetically engineered. The foreign gene can also be a synthesized DNA sequence for a product and the receiving crop is known either not to produce it or produce it in insufficient quantity. The introduced gene also includes elements such as promoters, termination sequences and sometime selection markers, all of which are required for making the gene express the protein it codes for and enable its detection in the process of genetic transformation. The whole composition is known as a “gene construct”. For simplicity, the construct can be referred to as “transgene”. The receiving plant is transformed into a GM plant by transferring the transgene construct either directly into the genome of the recipient organism through “ballistic bombardment” or through a bacterium known as *Agrobacterium tumefaciens* which has the capacity to transfer the gene construct into the recipient plant through infection. When the latter procedure is adopted, the resulting GM crop would have passed through the same procedures that the tissue cultured product passes through, known as the process of regeneration for successful transformation.

In contrast to the transformation techniques used for developing the GM crop, in the case of conventional plant breeding, usually two or more genotypes (known as parents) are hybridized to recombine the genes from both the parents desired to be brought together. The genes are tracked in the following generations through selection to finally end up in a stable genotype which is released as a “variety”. In this process, a large number of genes recombine from parental genotypes exchanging a large amount of genomic regions from the involved parents; the best combinations are selected consciously according to the objectives of the breeding program to be evaluated for performance and eventual release as a new variety.

One of the exceptions to this procedure is the hybrids where the evolved hybrid would necessarily have an equal genomic region from both parents. The other exception is the process of development of introgression line (also known as near-isogenic line) that results from a specific breeding process known as "backcross breeding" where the focus is to transfer only one gene from one parent (known as the donor parent) into another already established variety, known as the recurrent parent. In general, once stabilized by the integration of the transgene anywhere in its genome, the GM crop follows the same series of survival procedures like any other conventional variety of the crop. The difference lies however, in the limitless potential of the GM crop both in the way the new "transgene" integrates into the native DNA of the crop and the location on the chromosome where it integrates. Once integrated, the transgene can recombine like any gene when crossed with another variety of the same crop.

The GM crop variety (hybrid in terms of the farmer) and the commercial product of the GM crop (such as leafy foliage, fruit, grains, oil or fiber from the viewpoint of the consumer), will technically be substantially similar to its conventional counterpart. In terms of farmers, the GM crop will enable them to produce more or better-quality product while for the consumer it will add more value to the product for a better quality of life. Over the last two decades, the technology of genetic engineering of plants has undergone a series of refinements to ensure that the product which has incorporated a foreign gene in its genome is as safe as its conventional counterpart. The rigorous testing of the product for establishing its safety vis-à-vis the environment, human and animal health under the vigil of the regulatory processes in place, makes the GM crop a beneficial product. Depending on the gene incorporated in the GM crop, its value in differentiating it from its conventional counter product differs. For example, if an insect resistance is the feature of a GM crop, this will be valuable to the farmer in terms of reduced use of pesticides. The consumer would have the benefit of getting an undamaged product and no residual pesticides in the commercial product. The conventional product in contrast will be prone to have the insect pest or have pesticide residues in the commercial product to the disadvantage of both farmers and consumers. If the GM crop is produced to add value to the commercial product such as enhanced carotene content or minerals, the farmer will be able to obtain better marketability while the consumer will have healthful products for consumption.

Developments in gene cloning, transformation and regeneration of crop species led to an enhanced capability in developing transgenic lines in a wide variety of plant species. Crop species and specific genotypes in certain crop species that were found recalcitrant to tissue culture and transformation earlier are now routinely being transformed with various transgenes. Transgenic crops are already a field reality in many developed countries and also in some developing countries. Transgenic crop plants which are either being commercialized or in the product pipeline are those with insect resistance, herbicide tolerance, viral resistance, enhanced product quality and shelf life etc. In the near future, one can also expect release of transgenic plants for a wider variety of traits including fungal resistance, bacterial resistance and tolerance to a biotic stresses such as salt, water, cold and heat. Since 1996, there has been a rapid adoption of transgenic crops, mainly in the developed countries. From an area of 1.7 million hectares under transgenic crops in 1996, the coverage increased to 11 million ha in 1997, 27.8 million ha in 1998, about 40 million ha in 1999, 44.2 million ha in 2000, and an estimated 50 million ha in 2001. These figures do not include transgenic crop acreage in China, which was in fact the first country to deploy a transgenic crop, a virus resistant tobacco variety, on a commercial scale in 1992. Currently, more than 1,00,000 hectares are reportedly under transgenic crops in China. Field trials of transgenic crops have been conducted in over 45 countries, of which USA leads, followed by Argentina, Canada, Australia, Mexico, South Africa, Spain, France and China. Crops like Soybean, Maize, Cotton and Canola are predominant among the transgenic under commercial cultivation. Soybean covers about 52%, Maize30%, Cotton9%, and Canola around 9%, and potato less than 1% of the total area under transgenic crops.

Although transgenic traits and/or commercialization have been mainly limited at present to crops where there is an opportunity for value-capture, greater involvement of public sector organizations in transgenic research is already leading to development of transgenic lines in a wide variety of crop species, including rice, that are so far not targeted by the private sector. Many researchers were successful in obtaining genetically transformed plants in a variety of crop species by transferring one or two foreign genes endowing plants with traits such as resistance to herbicides, plant pests or pathogens. While these efforts are truly outstanding, the development of the nutritionally enriched 'golden rice' is indeed a remarkable achievement and a major leap. On a more humanitarian front, it may offer improved nutrition for billions of people in the developing nations who depend on rice as a staple food. On the technical front, the 'golden rice' created by plant molecular biologists at the Swiss Federal Institute of Technology in Zurich, with support from the Rockefeller Foundation, carries a total of seven foreign genes from two separate pathways: four encode enzymes that give rice strains the ability to synthesize β-carotene and three more genes enable the kernels to accumulate extra iron in a form that the human body can better absorb. This development could have an enormous impact considering the fact that vitamin A deficiency affects nearly 400 million people worldwide, leaving them vulnerable to infections and blindness. Iron deficiency- the most prevalent micronutrient deficiency, which a staple diet of rice can exacerbate- afflicts up to 3.7 billion people, particularly women, leaving them weakened by anemia and susceptibility to complications during childbirth. Since this whole endeavor was not industry-funded, the technology can possibly reach millions of farmers in developing nations, free of charge.

Commercialized GM Crops: The year 2009 saw increased commercialization of genetically modified (GM) crops. During the year, 14 million farmers (90 percent of whom were small and resource-poor farmers from developing countries) planted 134 million hectares of biotech crops in 25 countries. This is up from 13.3 million farmers and 125 million hectares (7 percent) in 2008. Trait hectares or "virtual hectares" reached 180 million hectares, up 14 million hectares from 2008. Eight of the 11 countries planting crops with stacked traits were developing nations. Brazil surpassed Argentina as the second largest grower of biotech crops globally.

Bt cotton in India has revolutionized cotton production in the country with 5.6 million farmers planting 8.4 million hectares in 2009, equivalent to a record 87 percent adoption rate. India gained US$1.8 billion from BT cotton in 2008 alone and reduced insecticide use by half. Biotech rice and the drought tolerant trait have been identified as the two most important drivers globally for future biotech crop adoption. During 2009, China accorded bio-safety clearance to insect-resistant rice. This is likely to spur faster development of rice and GM crops in other developing countries. Meanwhile drought tolerant maize is expected to be deployed in the United States in 2012 and sub-Saharan Africa in 2017. Other key highlights marking the beginning of the second wave of growth in 2009 include the approval of Smart Stacks, a novel biotech maize containing eight different genes for insect and herbicide resistance and planting in the United States and Canada of the first Roundup Ready 2 yield soybeans the first product of a new class of technology that allows more efficient, precise gene insertion to directly impact yields. Six European countries planted 94,750 hectares of biotech crops in 2009. The top eight countries, each growing more than 1 million hectares was: Brazil (21.4 million ha), Argentina (21.3 mha), India (8.4mha), Canada (8.2 mha), China (3.7 mha), Paraguay (2.2 mha) and South Africa (2.1 mha). The remaining countries included: Uruguay, Bolivia, Philippines, Australia, Burkina Faso, Spain, Mexico, Chile, Colombia, Honduras, Czech Republic, Portugal, Romania, Poland, Costa Rica, Egypt and Slovakia.

In a landmark decision on March 2, 2010, the European Commission has cleared the way for genetically modified potato to be grown in the EU- only the second GM product it has allowed. The starch of the Amflora potato can be utilized for industrial uses like making papers, and for animal feed but not for human consumption.

Common Misconceptions about GM crops:

1. GM crops are unsafe and harmful.
2. GM crops destroy natural genetic diversity.
3. Issue of foreign bacterial or animal genes in traditional crops.
4. GM crops increase yield and reduce soil fertility.

It is an opportunity to objectively assess the science and the ground reality in respect of the relevance of genetically modified crops for the country. Nobody seems to be against a technology-based solution to stagnating productivity in agriculture in the face of projected increase in human population. GM technology affords a unique opportunity to tackle biotic as well as biotic stresses, besides improving the nutritive quality of the feed stocks. Majority of the stockholders are not against the technology as such, but the standard concerns expressed are:

1. Environmental and health safety
2. Regulatory regimes for approval

It would be in the interest of the nation if valid scientific arguments are accepted so that one does not throw out the baby with the bath water. It is also the duty of the scientific community, which believes in GM technology, to address the concerns and keep evolving newer strategies to make the technology safe on the ground, as well as in the minds of the public. If vested interests dictate terms to dump the technology, it would be a great loss. India missed the industrial revolution as a subjugate nation and still paying a price in terms of development. It would be a great tragedy if it misses, as a free nation, the GM revolution that can address concerns of food security and mass nutrition (Padmanaban 2010).Concerns about commercialization of genetically modified crops, rapid advances in development and commercialization of transgenic crops in recent years have led to considerable apprehensions and concerns about the safety of the genetically modified plants for human and animal health and environment. Science genetic engineering provides an opportunity of mobilizing genes across the biological world, there are fierce debates going on regarding the bio-safety of transgenics. The concerns mainly stem from three major factors: (a) lack of information on the behavior of a gene transferred of an unrelated organism into alien genetic background; (b) possibility of transgene transfer from the transgenic plant to a weed or wild species, and (c) gene products that might cause adverse impact on human health and environment.

The world opinion on bio-safety of transgenic plants has got distinctly polarized in support or against the use of the genetically modified plants. The factors for the polarization are many. Corporate sector that has invested a huge amount of money is eager to quickly get returns on their investment and, therefore, favors a quick acceptance of this technology by the masses. The public and the media, on the other hand, would like to get convinced about the safety of such plants before their commercialization. Very few countries in the world have well-laid out bio-safety rules and regulations. The Indian regulatory agencies have established appropriate policies, laws, regulations and enforcement mechanisms for control of potentially problematic introductions, whether for testing, export and import or release of genetically modified organisms on a commercial scale. Besides these guidelines, it is imperative to also build scientific expertise, infrastructure and resources for adequate assessment of the possible risks during commercialization of genetically modified crops.

While supporters of the technology argue that the foods produced through biotechnology are just as safe, if not safer, than conventionally produced foods because they are subjected to highly rigorous testing, critics of genetically modified foods have even coined a new term 'Frankenfood' or 'Franskenstein foods' for genetically modified foods. Science-based risk assessment of genetically modified crop plants is the only way to effectively address public concerns, to dispel unwarranted myths and fears surrounding genetically modified foods, and instill confidence among the consumers about the biological safety of products derived from transgenic plants. Any technology or a product should not be out rightly rejected without proper evaluation. At this juncture, the solution given by most eminent scientist is the evaluation of each transgenic on a case-by-case basis regarding bio-safety.

Reliable and consistent expression of transgenes that have been introduced into plants is another vital requirement. While obvious changes in phenotypes caused by the presence of a transgene in a genetically modified plant would be relatively easy to assess during bio-safety assessment and field trails, subtle changes or effects would be difficult to estimate and could potentially be of significance under large scale production. We also now know that a surprisingly high proportion of primary transgenic plants, and their progeny show transgene instability and can be a major and potential challenge for the successful commercialization of transgenic varieties at least in some instances.

Need for a strategic approach towards agricultural biotechnology: Biotechnology it could be said, describes a pattern of expectations. National differences here mean that even in the era of instant communications, it still has different meanings across the world. In view of these realities, integrating biotechnology in agriculture is undoubtedly a long-term endeavor and certainly not an easy task. If knowledge and innovation are essential to meet productivity requirements, it is important that such needs are reflected in national objectives and priorities for food and nutritional security. In the long term, agricultural production enhancement programs have to become more efficient, effective and flexible.

When the Green Revolution technologies were introduced in the early 1960s, there was very little resistance mainly due to the fact that the countries like India were reeling under heavy food deficits and there was strong policy support. The scenario is now different. Introduction of modern crop science in developing countries, led to the production of new and improved seeds. The Green Revolution was possible because of a free and unfettered exchange of germplasm, including varieties, indigenous germplasm and wild relatives all over the world. As stated by Rasmussen (1996), nearly half of the progress made by the crop breeders in the past can be attributed to germplasm exchange. Not many of the products of agricultural research were patented at that time. There is now valid and widespread concern that Plant Variety Protection (PVP) and plant or gene patents will restrict access to germplasm, with deleterious consequences for future breeding achievements. Recent developments in biotechnology for crop improvement have motivated much of the concern over PVP and other forms of Intellectual Property Rights (IPR), as well as concern over germplasm exchange and developing nations' access to novel agricultural technologies. The world is not the same after the World Trade Agreement was signed in 1994. All the member countries are obliged to strengthen the IPR in their countries. Technology fee may, therefore, become a considerable part of the cost of seeds resulting from new technologies. Notwithstanding some of the positive effects of adoption of IPR in intensive production systems, there are certain aspects of IPR that may hinder developing countries from reaping the full potential benefits of biotechnology. Apprehensions also about the control of intellectual property by the multinational corporations and the possibilities of monopoly over the seed sector constitute an important reason for resistance against the biotechnology products in some countries. The issues related to IPR also highlight the necessity of (i) strong participation of public sector institutions for many more decades to come, in developing biotechnology products of value to the farmers, (ii) enhance support from the government in scientific research and development and (iii) more effective dissemination of the technology.

Another element in the ongoing debate about the possible impact of Gene Revolution is the possible distribution of gains from the technology. Opinions are once again divided about the possible benefits; biotechnology can provide to the resource-rich and resource-poor farmers. The appropriateness of any technology will depend on whether farmers have access to it and on the relevance as the improvement it is capable to bring about. The experience of the Green Revolution shows that the rich farmers could reap the early gains from any new technology. However, institutional mechanisms have made the new technologies accessible even to the resource-poor farmers subsequently. One may expect a similar pattern even in case of products of agricultural biotechnology. Whether existing public technology transfer mechanisms are likely to be adequate for taking biotechnology products to the farmers and consumers needs to be carefully considered, is another key issue that merits immediate attention. Clearly, each country will need to make its own decisions with respect to policies and priorities for the application of agricultural biotechnology. At the same time, it is important that biotechnology policies and programs are closely integrated in the framework of the problems confronting agriculture. Equally important is that biotechnology should be linked realistically to the scientific and technological capacities and level of agricultural development in the country concerned.

Emphasis on capacity building and team building: The issue of capacity building for agricultural biotechnology has many different facets, and implies, at the very least, financial and human resources, appropriate infrastructure and institutions, and supportive government policies. Although the situation with respect to the availability of scientific personnel varies considerably even among the developing countries, education and training of scientist is a key element in building biotechnological capability. Many countries in the developing world including India require support for capacity and institution building. Biotechnology can complement, but will not supersede, underlying scientific capacity in vital areas such as plant breeding. Indeed, in situations where plant breeding capacity is weak and where the seed sector is under-developed, it may make good sense to give priority to strengthening those capacities, before diverting a major share of scarce resources to biotechnology research. Otherwise, there is a possible danger of frustration at not being able to see the fruits of research translated into biotechnological products. Where biotechnology is embedded in seed, an effective seed sector will be required for the development of biotechnological products and efficient dissemination of the same to the farmers. Therefore, adequate attention also needs to be given to building national capacity in complementary underpinning technologies and infrastructure which are necessary to ensure the transition from the laboratory to the end user. For instance, growing demand for bio-pesticides would require more efficient, large-scale bio-processing capacity. Similarly, strong plant breeding capacity and a seed industry which incorporates not only production, but also quality control and certification as guiding principles are essential for effective development and dissemination of biotechnology products, particularly those embedded in seed.

Constituting effective research teams, particularly inter-disciplinary teams, is another important aspect. Capacity building in areas such as biotechnology cannot be complete without adequate attention to team building. This, of course, should not only be limited to constituting but also retaining and strengthening research teams. If we are to efficiently tap the power of biotechnology for sustainable food security, we must blend very specialized research disciplines in terms of scientists seeking appropriate outcomes that could have an immediate impact in farmers' fields. Isolated interventions will have very little impact and limited value at best.

The issue of GM crops has attracted a great deal of attention both worldwide and in India. Proponents view GM technology as a major tool for the development of crops having improved traits such as greater yield, disease and pest resistance, drought tolerance, and shelf life, in addition to reducing environmental and health hazards such as those caused by application of chemical pesticides. Opponents raise a number of concerns, starting from general and ethical concerns about consuming food that has been genetically altered by introducing genes across the normal species barriers, and the possible unforeseen consequences this could have; concerns about the potential risks arising from specific genes such as antibiotic or herbicide resistance genes that are introduced into a species, escaping to other organisms or species; as well as concerns about the effects on societies in developing countries which account for the major population and food markers of the world, of the spread of GM crops since much of the capacity for and control of GM technology (especially the most advanced GM technology) is often covered by intellectual property (IP) that resides with large multinational corporations (MNCs). The concern is that MNCs would come to exercise undue influence, should agriculture in these countries become overly dependent on GM crops.

Non-GM agricultural technology, which is much less controversial, relates to methods that do not involve transfer of genes across species, i.e. the use of transgenic approaches. Plant (and animal) breeders have for centuries relied on variation that exists within the gene pool of a species to breed varieties having features that are suitable for specific purpose and environments.

In fact, genetically engineered changes are precise, and the changes introduced are understood at the molecular level compared to classical methods of generation of mutants and breeding procedures. Similarly, it is also clear now that good laboratory practices adopted in microbiology laboratories dealing with infectious organisms are adequate to carry out the gene manipulations employing genes from such sources. Nevertheless, introduction of genetically engineered species into the environment has to be done with great caution and special procedures and controls have to be evolved case by case. In the final analysis, the tremendous potential of new biotechnology for the welfare of the society is the overriding factor. If it has potentials to be misused, the culprit is the human mind and sense council for self-preservation should channel the efforts towards the beneficial effects. The facts that new biotechnology has kindled renewed interest in Biology as a discipline should gladden the hearts of everyone with a scientific temper.

Gene editing proves way forward for improved crop varieties : Indian scientists are making progress in using gene editing to develop Vitamin A rich banana and improved varieties of rice, millets, pulses and tomato even as absence of a regulatory policy prevents their release for commercial use. There is a fresh spotlight on gene-editing with E Charpentier and J. Doudna winning the noble prize (2020) for developing a method (CRISPR – cas9) for genomic editing. This process may be less problematic for opponents of GM despite discussions on the technologies potential to impact human heredity. The Indian research is, however in crops. Unlike GM technology which introduces foreign DNA (insertion from a different species), gene-editing modifies existing genes in a precise manner by making specific targeted changes in the genome of an organism. Gene-editing should not be treated as transgenic, and it should not come under the same regulatory system which has been regulating GM crops. The programmable gene-editing system allows scientists to make changes in the genome of an organism to come out with nutrition rich, high yielding, disease resistant, herbicide tolerant and a biotic stress tolerant variety of crops which can substantially reduce impact costs of farmers. The Hyderabad based International Crop Research Institute for the semi-arid tropics (ICRISAT)has signed an agreement with US based Cortiva-agri science, which holds license for MIT and Harvard CRISPR technologies to get access to CRISPR related resources for crop improvement. This technique has opened enormous opportunities for creating desired variations in crop plants, animals, fish and micro-organisms.

Recent developments in the areas of molecular biology, genetic engineering, *in vitro* methodologies and crop transformation have made possible to mobilize genes in an organism of interest from across the biological kingdom. The whole spectrum of gene technology is now routinely and successfully applied to a wide range of problems in plant biology, pathology, breeding and plant improvement. The coming decades will bring increasingly intense research in this field, in an increasing number of institutions across various developed and developing countries. India is one among the few developing countries at present with scientific infrastructure, human resources and the capability to exploit biotechnology for the benefit of society in general and farming community in particular. What is significant is the key role public sector institutions in India have been playing in developing transgenic lines, particularly for traits of interest that are difficult to modify using conventional plant breeding and also in crops which are not much interest to the corporate sector either due to lack of adequate opportunities for value capture or market benefits.

While some progress has been made in the capacity building of National Agricultural Research Systems in crop Biotechnology, the task ahead is to develop integrated national programs that facilitate the efficient application of Biotechnology tools for enhancing crop productivity, managing emphasis must be given to employ Biotechnology more towards solving problems related to increased and sustained crop production and productivity.

If people are to be fed in the coming decades and if agriculture has to serve as a catalyst for national growth, it is imperative that we make judicious use of all available technologies and inputs at our disposal through an effective strategic approach. The current challenges indeed are more complex, if not more formidable, than those faced by India during the Green Revolution era. Amidst all the din of protests and denunciation of applications of biotechnology in agriculture, it must be remembered that every human activity and every new technology has inherent risks, be it electricity, be it automobiles or be it new drugs or vaccines. As an intelligent society, we have the responsibility to rationalize the risk based on scientific data and societal benefits and make sensible decisions. Countries must prepare a balance sheet depicting in clear terms the beneficial and harmful effects associated with transgenic on a case-by-case basis. In situations where there is a perceptible advantage in using a genetically modified plant, it needs to be encouraged. What is extremely important is to exercise all the options in front of us, be it genetic engineering or be it organic farming, wisely and carefully to counter the challenges facing the agricultural sector.

Having spent 38 years of my life, giving the best to the university, brought awards and appreciation and 11 major research projects for the department. I have been a Program Coordinator of five major projects under the Special Assistance Program of UGC-DRS-1(2009-2014), DRS II (2016- 2021) L; DST-FIST I (2005-2010); DST-FIST II (2011-2016) and DBT – HRD project (2008-2013). Have published over 220 research papers in reputed journals which have been cited frequently, causing **citation index 5451 with 'h' index 44** and **'i10' 135**. This speaks of my unparalleled contribution towards R&D in plant sciences.

Let us dream and dream for the future. Let us realize that probably the only thing that is impossible in this universe is the one we cannot possibly think of. If we can visualize, we can achieve. Who knows one day we may be able to transform C_3 plants to C_4 plants, resulting in enhanced photo synthetic efficiency through better CO_2 assimilation, thereby elevating the adverse effect of some of the global climatic changes! Who knows we may be able to develop and cultivate rice plants with negligible methane gas emission! Who knows we may be able to genetically alter crop plants that can effectively take care of pollutants and toxic substances in the soil, water and air! Yes, we can possibly achieve these and many more through judicious application of frontier technologies in conjunction with the time-tested methodologies. What we really need are dedicated scientific manpower, excellent infrastructure, adequate financial support and most importantly, a positive and strong "will" that can transform such dreams into realities.

Lastly, I take this opportunity of thanking the various office bearers of the society for their kind and willing cooperation and untiring work throughout the year. All members of the society and myself will uphold the ideals of the society and will work to the best of our abilities to preserve, protect and take it to greater heights on the path shown by our eminent predecessors. I, on behalf of the society, also welcome our new Fellows and members.

Plant scientists now have a central role in society.

REFERENCES

Anis M and Ahmed N (eds) 2016. *Plant tissue culture: Propagation, Conservation and Crop improvement* Springer.

Ahmad N and Anis M 2007 Rapid clonal multiplication of a woody tree, *Vitex negundo* L. through axillary shoots proliferation. *Agroforestry Systems* **71** 195-200.

Ahmad N, Faisal M, Anis M and Aref IM 2010 *In vitro* callus induction and plant regeneration from leaf explants of *Ruta graveolens L*. South *African J Bot* **76** 597-600.

Ahmad N, Javed SB, Khan MI and Anis M 2013

Rapid plant regeneration and analysis of genetic fidelity in micropropagated plants of *Vitex trifolia*: an important medicinal plant. *Acta Physiol Plant* **35** 2493-2500.

Ahmed MR and Anis M 2012. Role of TDZ in the quick regeneration of multiple shoots from nodal explants of *Vitex trifolia L.* - An important medicinal plant. *Appl Biochem Biotechnol*. **168** 957-966.

Ahmed A and Anis M 2019. Meta-topolin improves in-vitro morphogenesis, rizhogenesis and biochemical analysis in *Pterocarpus marsupium* Roxb, a potential drug yielding tree. *J plant growth regulatio*n **28** 1007-1016

Anis M, Faisal M and Singh SK 2003 Micropropagation of Mulberry (*Morus alba* L.) through *In vitro* Culture of Shoot tip and Nodal Explants. *Plant Tissue Cult.* **13(1)** : 47-51

Anis M, Varshney A and Siddique I 2010 *In vitro* clonal propagation of *Balanites aegyptiaca* (L.) Del. Agroforestry Systems *78 151-158*

Faisal M and Anis M 2003 Rapid mass propagation of *Tylophora indica* Merrill via leaf callus culture. *Plant Cell Tiss. Organ Cult.* **75** 125–129.

Faisal M and Anis M 2006 Thidiazuron induced high frequency axillary shoot multiplication in *Psoralea corylifolia*. *Biologia Plantarum* **50** 437-440.

Faisal M, Siddique I and Anis M 2006 in-vitro rapid regeneration of plantlets from nodal ex plants of *Mucuna pruriens*- a valuable medicinal plant. *Ann.appl.biol* **148** 126

Faisal M, Ahmad N and Anis M 2005 Shoot multiplication in *Rauvolfia tetraphylla* using thidiazuron. *Plant Cell Tissue & Organ Culture* **80** 187-190.

Faisal M, Alattar A A, Ahmed N, Anis M and Ghazi AK 2012. Assessment of genetic fidelity in *Rouvolfia serpentine* plantlets grown from synthetic (encapsulated) seeds following *in-vitro* storage at 4 degree C. *Molecules* **17** 5050-5061

Fatima N, Ahmad N, Anis M and Ahmad I (2013) An improved in vitro encapsulation protocol, biochemical analysis and genetic integrity using DNA based molecular markers in regenerated plants of *Withania somnifera L. Ind Crop products* **50** 468-477.

Husain M K and Anis M 2009 Rapid *in vitro* multiplication of *Melia azeadrach* L. (A multipurpose woody tree). *Acta Physiol Plant.* **31** 765-772.

Husain M K and Anis M 2006a Rapid *in vitro* propagation of *Eclipta alba* (L) Hassk by shoot tip culture. *J. Plant Biochemistry and Biotechnology* **15** 147-149.

Hussain M K and Anis M 2006b Rapid *in vitro* propagation of *Eclipta alba* (L.) Hassk. Through high frequency axillary shoot proliferation. *Acta Physiologiae Plantarum.* **28** 325-330.

Husain M K, Anis M and Shahzad A 2010 Somatic embryogenesis and plant regeneration in *Pterocarpus marsupium* Roxb. Trees **24**: 781-787.

Hussain S A, Ahmed N, Anis M and Alatar AA 2019. Influence of Meta-topolin on *in-vitro* orgenogenesis in *Tecoma stans L*, assessment of genetic fidelity and phytochemical profiling of wild and regenerated plants. *Plant cell, tissue and organ culture* **138** 339-351.

Jahan A A and Anis M 2009. *In-vitro* rapid multiplication and propagation of *cardiospermum halicacabum L* through axillary bud culture. *Acta physiol plant* **31** 133-

138

Jahan A A, Anis M and Aref I M 2011 Assessment of factors affecting micropropagation and *ex vitro* acclimatization of *Nyctanthes arbor-tristis* L. *Acta Biologica Hungarica* **62** 45-56.

Khan H, Siddique I. and Anis M (2006). Thidiazuron induced somatic embryogenesis and plant regeneration in *Capsicum annuum* L. *Biologia Plantarum.* **50** 789-792.

Khan M I, Ahmad N and Anis M 2011 The role of cytokinin on *in vitro* shoot production in *Salix tetrasperma* Roxb: A tree of ecological importance. *Trees-Structure and Function* **25** 577-584.

Khanam M N and Anis M 2018 Organogenesis and efficient in-vitro plantlet regeneration from nodal segments of *Allamanda cathartica L.* using TDZ and ultrasound assisted extraction of quercetin. *Plant cell, tissue & organ culture* **134** 241-250.

Khanam M N, Anis M and Ahmed S 2018 Establishment of adventitious root cultures of *Allamanda cathartica L* for the production of iridoid glycosides and its identification using HPTLC MS. *Industrial Crops and Products* **125** 198-206.

Khanam M N, Javed S B, Anis M and Alattar AA 2020. Meta-topolin induced in-vitro regeneration and metabolic profiling in *Allamanda cathartica L.* Industrial crops and products **145** 111944.

Naz R and Anis M 2012 Acceleration of Adventitious Shoots by Interaction Between Exogenous Hormone and Adenine Sulphate in *Althaea officinalis* L. *Appl Biochem Biotechnol* **168** 1239–1255.

Padmanaban G 2010 GM crops in India, Beyond BT brinjal. *Biotech news* **5 (2)** 64.

Perveen S, Anis M and Aref I M 2013 Lipid peroxidation, H_2O_2 content, and antioxidants during acclimatization of Abrus precatorius to ex-vitro conditions. *Biol Plant* **57** 417-424.

Perveen S, Javed S B, Anis M and Aref IM (2013) Rapid in vitro multiplication and ex vitro establishment of Caribbean copper plant (*Euphorbia cotinifolia L.):* an important medicinal shrub. *Acta Physiol Plant* **35** 3391-3400.

Sharma R P 2010 GM Technology: Responsible and Purposeful use. *Biotech news* **5 (2)** Page 68.

Shazad A, Faisal M, Naseem A and Anis M 2012. An efficient system for *in-vitro* multiplication of *Osimum basilicum* through nod culture. *A*fri. *J plant Bio tech* **11** 6055-6059.

Siddique I and Anis M 2007a An improved plant regeneration system and *ex vitro* acclimatization of *Ocimum basilicum* L. A*cta Physiologiae Plantarum* **30** 493-499.

Siddique I and Anis M 2007b Rapid micropropagation of *Ocimum basilicum* L. using shoot tip explants pre - cultured in thidiazuron supplemented liquid medium. *Biologia Plantarum* **51** 787-790.

Siddique I, Anis M and Aref I F 2010 In Vitro adventitious shoot regeneration via indirect organogenesis from petiole explants of *Cassia angustifolia* Vahl.-a potential medicinal plant. *Appl Biochem Biotechnol* **162** 2067–2074.

Varshney A and Anis M 2013 Evaluation of clonal integrity in desert date tree (*Balanites aegyptiaca* Del.) by inter-simple sequence repeat marker assay. *Acta Physiol Plant* **35** 2559–2565.

Varshney A, Anis M and Aref IM 2013 Potential role of cytokinin-auxin synergism, antioxidant enzymes activities and appraisal of genetic stability in *Dianthus caryophyllus* L.-an important cut flower crop. *In Vitro Cell Dev Biol-Plant* **49** 166-174.

Varshney A, Shahzad A and Anis M 2009 High frequency induction of somatic embryos and plantlet regeneration from nodal explants of *Hygrophila spinosa* T. Anders. *African J Biotech* **8** 6141-6145