Role of Genetic Modification in Developing Climate Smart Agriculture to Ensure Sustained Food Security

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Received: 29 October 2012 / Accepted: 2 November 2012 / Published online: 25 November 2012
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I was a contemporary of James Watson and Francis Crick at the University of Cambridge, UK, during 1950–52. I was aware of the fact that they were working on the molecular structure of DNA in association with Maurice Wilkins and Rosalind Franklin since I used to visit the Cavendish Laboratory to attend lectures by Prof Max Perutz. Their publication on the double helix structure of the DNA molecule appeared in *Nature* early in 1953 [2, 7, 8]. I was then at the Genetics Laboratory of the University of Wisconsin, Madison, USA. Since then, I have been following the explosive progress of the science of molecular genetics, opening up uncommon opportunities for transferring genes across sexual barriers. I was deeply interested in this development, since my work in the early 1950s related to the transfer of genes in tuber-bearing *Solanum* species for characters like frost tolerance and resistance to the golden nematode, *Heterodera rostochiensis*. The donor for frost tolerance was the species *S. acaule* from the Lake Titicaca region of Peru-Bolivia, while the donor for golden nematode resistance was *S. polyadenium*. Achieving crosses between these species and *S. tuberosum* was extremely difficult, since the foreign pollen were getting inhibited in the stigma and style. I had to remove the stigma and replace it with an artificial medium which promoted pollen germination [4]. This technique later came to be known as the ‘Swaminathan artificial stigma method’. *All this would not have been necessary if the recombinant DNA technology had existed then.* Thus, the Watson–Crick–Wilkins–

Franklin discovery paved the way for fulfilling the dream of plant and animal breeders and microbiologists with respect to producing novel genetic combinations of applied interest. The award of the Nobel Prize to my colleague at the University of Wisconsin Dr. Joshua Lederberg, for his work on microbial transformation further stimulated my interest in this fast growing area of science.¹ The US National Academy of Sciences invited me in 1982 to deliver a lecture on ‘Biotechnology Research and Third World Agriculture’, where I emphasised the need for Third World countries, to master all recent developments in Genetics [5].

In 1980, when I joined the Union Planning Commission at the invitation of the then Prime Minister of India Mrs. Indira Gandhi, I got a National Biotechnology Board set up to achieve synergy and coordination among the work in progress in molecular genetics and genetic engineering under the umbrella of different scientific organisations like ICAR, CSIR, ICMR, Department of Atomic Energy and UGC. I served as the first chair of the National Biotechnology Board. Later, it was converted into a Department of Biotechnology during the tenure of Prime Minister Rajiv Gandhi, with Dr. S. Ramachandran serving as its first Secretary.

During the last 30 years, the Government of India has invested a considerable amount of money in creating the infrastructure essential for advanced research in the broad

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¹ **Dr. Joshua Lederberg, Nobel Laureate in Medicine and Physiology:** ‘I can think of no one who has combined the insights of the cutting edges of biological science, with attention to the most urgent of human needs, with the competence, devotion and energy that Dr. M. S. Swaminathan has given. The world is and will be a better place on account of his contributions to its welfare’ [1].

areas of biotechnology in general, and in genomics and genetic engineering in particular. The Government of India is also hosting the International Centre for Genetic Engineering and Biotechnology (ICGEB) in New Delhi. Both in India and abroad, much investment has been made for human resource development in the areas of environmental, medical, industrial, food and agricultural biotechnology. However, in the field of agricultural and food biotechnology, there are concerns about biosafety, environmental safety, biodiversity loss and food safety. The Global Biodiversity Convention adopted at Rio de Janeiro in June 1992 has the following clauses with respect to biotechnology:

Each Contracting Party shall take legislative, administrative or policy measures, as appropriate, to provide for the effective participation in biotechnological research activities by those Contracting Parties, especially developing countries, which provide the genetic resources for such research, and where feasible in such Contracting Parties.

The Parties shall consider the need for and modalities of a protocol setting out appropriate procedures, including, in particular, advance informed agreement, in the field of the safe transfer, handling and use of any living modified organism resulting from biotechnology that may have adverse effect on the conservation and sustainable use of biological diversity.

This resulted in the adoption of the Cartagena Protocol for biosafety. The Cartagena Protocol on Biosafety to the Convention on Biological Diversity is the only international environmental agreement that is concerned exclusively with the transboundary movement (i.e. trade) of products of modern biotechnology that are living modified organisms. It applies to the transboundary movement, transit, handling and use of all living modified organisms (LMOs) that may have adverse effects on the conservation and sustainable use of biological diversity, taking into account risks to human health. GM foods are considered only if they are LMOs that may be subject to transboundary movement for direct use as food, feed or for processing. The protocol does not apply to processed food products, nor does it address the food safety of LMOs that are for food, feed or processing. The Cartagena Protocol lays emphasis on the precautionary principle and prior informed consent in relation to the import and export of LMOs.

In 2004, a Committee set up by the Ministry of Agriculture of the Government of India under my chairmanship made several recommendations [6], of which the following are important:

- (a) Policy: ‘The bottom line of our national agricultural biotechnology policy should be the economic well being of farm families, food security of the nation,

health security of the consumer, biosecurity of agriculture, protection of the environment, and the security of national and international trade in farm commodities’.

- (b) Choice of Research Problem: The choice of problems for genetic modification should be done very carefully. Wherever possible, marker assisted selection should be used. Genetic combinations, which can be achieved without going through the recombinant DNA route should be preferred, unless the particular research goal needs para-sexual transfer of genes, as in the case of bioremediation.
- (c) Special All India Coordinated Trials: *ICAR should organise a special All India Coordinated Research and Testing programme for GMOs*, handled by trained personnel with adequate safeguards in relation to gene transmission.
- (d) Regulatory Authority: *The regulatory Authority should have its own testing and screening facilities* and should not just depend upon solely on the data furnished by breeders. It should have the capacity to perform the functions now being carried out by the following three regulatory agencies of USA:
 - EPA: Environmental Protection Agency
 - FDA: Food and Drug Administration
 - APHIS: Agricultural Plant Health Inspection Service of USDA

Without a professionally competent and well equipped regulatory system, public apprehensions on risks will persist.

Recently, the Committee on Agriculture of Indian Parliament, headed by Mr. Basudeb Acharia with 31 Members of Parliament drawn from both the Houses (Lok Sabha and Rajya Sabha) and from all Political Parties has submitted a very detailed Report on ‘Cultivation of genetically modified food crops: Prospects and Effects’ [3].

The Committee has unanimously recommended that ‘till all the concerns voiced in the Report are fully addressed and decisive action is taken by the Government with utmost priority to put in place all regulatory, monitoring, oversight, surveillance and other structures, further research and development on transgenics in agricultural crops should only be done in strict containment, and *field trials under any garb should be discontinued forthwith*’. The Committee also suggested, ‘What the country needs is not a biotechnology regulatory legislation but an *all encompassing umbrella legislation on biosafety*, which is focussed on ensuring the biosafety, biodiversity, human and livestock health, environmental protection, and which specifically describes the extent to which biotechnology, including modern biotechnology, fits in the scheme of things without compromising with the safety of any one of

the elements mentioned above. The Committee, therefore, recommend to the Government with all the power at their command to immediately evolve such a legislation after due consultation with all stakeholders and bring it before Parliament without any further delay. In this context, the Committee would advise Government to duly consult the Norwegian Law, which emulates this spirit to a large extent’.

The Norwegian Act No. 38 of 2nd April 1993, relating to the production and use of Genetically Modified Organisms focuses on biosafety, ethics and sustainable development without any adverse effects on the health and the environment. **In my view, the suggestion that India should enact a comprehensive law on Biosafety on the lines recommended by the Parliamentary Committee on Agriculture is a sound one and should be acted upon immediately.**

In India, resistance to food and agricultural biotechnology involving genetic engineering has been growing during the past 2 decades, partly due to fears about the potential adverse impact of GMOs on human health, biodiversity and the environment, and also with respect to issues such as ‘who controls the technology and who will have access to it?’ Some of the other concerns are:

- The private sector, particularly multi-national companies, conduct much of the advanced research in crop genetic modification. This, therefore, raises the question whether food security will be controlled by a few large multi-national corporations under well guarded patent rights?
- For-profit research, covered by intellectual property rights, is increasing in this field; will it lead to social exclusion in access to new technology?
- The recombinant DNA technologies involving the use of antibiotic markers, have adverse implications for human health.
- The currently existing regulatory structure is not adequate to weighing risks and benefits in a transparent and credible manner.

Can we take advantage of the beneficial aspects of recombinant DNA technology by greater investment in public good research, as for example in the breeding of crop varieties whose seeds farmers can keep and re-sow, rather than concentrate only on hybrids whose seeds the farmers have to buy every crop season? How can we develop institutional structures which can help to allay the apprehensions of the public?

The Royal Society, one of the oldest Science Academies in the world, established many years ago a **Committee on Public Understanding of Science (COPUS)**, and later also constituted a **Committee on Political Understanding of Sciences (COPUS)**. In democratic societies there is greater

need for public and political understanding of the scientific facts underpinning events of great significance, such as biodiversity loss and climate change. While medical biotechnology has not generated fears about biosafety and environmental safety, food and agricultural biotechnology has evoked strong opposition. An area in medical biotechnology which is controversial is cloning. Generally, therapeutic cloning is acceptable, while reproductive cloning is not. In the case of crop biotechnology, the fears relate to biosafety and environmental safety, adverse impact on biodiversity and long term impact on human and animal health. The controversy relating to Bt brinjal and the moratorium on its release imposed by the then Indian Minister for Environment and Forests are examples of the lack of confidence in the existing regulatory procedures. The Hon’ble Supreme Court of India has also raised several issues of public importance with reference to genetically modified crops and foods. Several State Governments have imposed a ban on the testing of GMOs. The Kerala Government has not allowed even the testing of genetically modified Rubber, although we urgently need rubber clones tolerant to higher temperature.

Obviously, powerful scientific innovations like genetic modification require professionally led regulatory structures. The Government of India has developed a Biotechnology Regulatory Authority Act for being discussed in Parliament. As mentioned earlier, the Standing Committee on Agriculture of Parliament headed by Mr. Basudeb Acharya has recommended that we should adopt a **comprehensive Biosafety Act [3]**. The aim of the Act is to provide a professional and transparent Regulatory Body, which inspires public, political, professional and media confidence.

The Department of Biotechnology has initiated a programme for organising DNA Clubs in Schools in order to familiarise young scholars with the implications of the human genome, rice genome, genetic modification, micro propagation and other aspects of biotechnology for human wellbeing. The genetic literacy movement is a welcome initiative. As science progresses, more and more of such issues of public concern will grow. The role of scientists in the area of public information and education will increase. **We need a cadre of Science Communicators possessing both proficiency in science and mastery of communication.** I am reminded of Prof C. V. Raman who used to deliver lectures for school students on topics like, ‘Why the Sky is Blue’ or ‘Structure of Diamonds’ with great clarity and lucidity. I have seen thousands of young students listening to him in pin drop silence, digesting every word and idea that he expressed. We need Science Communicators who can explain to the general public in local languages the significance of important scientific discoveries. **Biodiversity and Biotechnology need priority attention in efforts designed to bridge the Scientist–Society perception gap.**

Since the rediscovery of Mendel's Laws of inheritance in 1900, geneticists have been searching for methods for creating novel genetic combinations. Whole genome combinations, for example in the case of *Triticale* (wheat–rye hybrid) as well as polyploidy and aneuploidy were used for this purpose. Induced mutations attracted attention for achieving the desired breeding goals, as for example, inducing straw stiffness and height reduction through *erectoides* mutants in barley in Sweden. With the advent of molecular breeding it has become possible to construct genes for a wide range of characters with greater precision. Molecular breeding can be described as 'precision breeding' and the pathways are both molecular marker assisted breeding and recombinant DNA Technology. Varieties developed through Marker Assisted Selection are eligible for certification in organic farming, while GMOs are not. Hence, breeders should take to the non-GMO pathway wherever this is possible to achieve the desired goal. At the same time research should be intensified in areas like environmental and medical biotechnology where scientists and the public share common aspirations.

Science is a continuum and scientific knowledge will grow as long as there are creative minds concerned with human wellbeing. What is important is that we should not worship any particular scientific tool, but should use such technologies or a combination of technologies (e.g. Mendelian and Molecular) that will take us to the desired goal

speedily and surely. This is the only way we can develop climate smart agriculture for ensuring sustained food security in an era of global warming.

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