water at the right time, by analysing soil moisture and measuring soil salinity. This system of monitoring and controlling irrigation not only increases plant yield, but also helps decrease water and power consumption, thus preventing global warming.

Detailed deliberations was made under theme 5 on 'Waste management'. Novel techniques for waste management system like segregation, collection, treatment and disposal of waste, recovery, reuse and recycling of waste, advanced thermal treatment (ATT) and incineration with energy recovery that reduces global warming were discussed. Utilization of planted gravel system for phytoremediation of sewage in villages and townships which produce sewage on a small scale, is a sustainable option to use potable water. To improve legislative measures for sustainable development of wetlands integrated novel and clean methods for recycle and reuse of garden waste, plant debris, plastic waste, electric waste and glass wastes were discussed.

Under theme 6, sustainable urban management was discussed at length. Implementation of sustainable streetscape design for water management and flood control in cities like Chennai was discussed. Green urbanization is an attempt to shape more sustainable places, communities and lifestyles to consume less of the world's resources. Several features of green urbanism like renewable energy source, carbon neutrality, distribution, eco-efficiency, biophilic source, and sustainable transport were discussed. Green urbanization is the need of the hour, and there was a discussion on converting metro cities into green cities. Green solutions for improving indoor air quality by growing plants which absorbs benzene from air-conditioners and volatile organic compounds that are hazardous to health were also discussed.

Theme 7 dealt with reduction and elimination of pollutants and toxins. In his keynote address, Hong Ming Wong (Hong Kong University) explained the presence of mercury, lead and cadmium in fish, which is a major part of his country's diet, due to industrial contamination. He discussed in detail the removal of pollutants at source contamination and eliminating them before contaminated water reaches the sea. Strategic approaches for the conservation and management of lakes in Bengaluru, and the need for watershed management in a participatory approach by institutes, organizations and individuals were the main topics discussed. Novel technologies for bioremediation of pollutants like arsenic from soil and water by microbial transformation of arsenic residues using thermophilic bacteria, yeast and fungi and also utilization of prokaryotic microbes as biosensors to detect arsenic pollutants in environment were discussed. Bioadsorbents from agricultural waste like rice husk, spent grain, sugar cane and fruit waste reduce the concentration of heavy metals to a low level. Use of *Commelina benghalensis* as a low-cost green absorbent for removal of hexavalent chromium from aquatic environment was acknowledged. Use of agro waste like lignocelluloic waste to improve laccase production in bacteria, which is used for effluent detoxification and decolorization of textile dye; degradation of pesticides by bacteria and fungi isolated from coffee plantation soil; use of *Aeromonas punctata* in the degradation of reactive black 5 dye; cypermethrin degradation by *Serratia nematodiphila*, were discussed. Isolation and characterization of plastic-degrading bacteria from the soil, and microbial control of toxin producing cyanobacterium in hyperutropic lake using algicydal bacteria and cyanophages were also discussed. Bioremediation using *Pseudomonas*, a potential bacteria for treatment of diesel contamination, oil clean-up by indigenous microbes like fungi, *Brevi bacterium*, actinomycetes, bacterial remediation of hydrocarbons, antibiotics and cyanotoxins using *B. cereus* and *E. lugwidii* were discussed.

The use of nanotechnology for photocatalytic degradation of industrial dye effluents with silver-doped zinc oxide and amine functionalized magnet nano adsorbent for platinum removal from acidic aqueous solution were discussed. Usage of biodegradable polymer produced by renewable resources against synthetic polymer in different industries like medical (surgical structures, drug delivery systems), agriculture (agriculture mulches and controlled release of agriculture chemicals), and food (edible coating, food packaging and active packaging systems) for better waste disposal was also discussed in brief.

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MEETING REPORT

Genome editing technologies*

The XV Genetics Congress Trust is a not-for-profit organization established to promote the science of genetics with emphasis on genetics education for public good. As a part of its activity, the Trust organized a one-day meeting on genome editing technologies. The meeting was chaired by M. S. Swaminathan and participants included Soumya Swaminathan (Department of Health Research/Indian Council of Medical Research) and T. Mohapatra (Department of Agricultural Research and Education/Indian Council of Agricultural Research), V. L. Chopra, and about 20 leading scientists and science administrators from different government laboratories, research institutions and universities. Also present were representatives from Department of Biotechnology (DBT) and Review Committee on Genetic Manipulation (RCGM). The objectives of the meeting were: (i) to review the latest developments on genome editing technologies, including

*A report on the National Consultation meeting on Genome Editing Technologies held on 23 November 2016 at National Agricultural Science Complex, New Delhi and organized by the XV Genetics Congress Trust.

regulatory issues, (ii) to share information about the steps initiated/contemplated by government agencies such as DBT, ICMR and ICAR in the area of gene editing; (iii) to discuss strategies to promote the development and deployment of the technology to address some of the pressing problems facing agriculture, animal sciences and human health; and (iv) to deliberate on policy issues for regulating the new technology.

After an initial brief on technology status, Soumya Swaminathan and Mohapatra presented a broad outlook of gene editing technology in their relevant areas. S. R. Rao (Advisor, DBT) highlighted the policy issues surrounding the application of genome editing technologies and the actions initiated by DBT to deal with the same. The priority setting for research was discussed under four categories, namely crops, animal sciences, fisheries and human health sciences. The enabling policy issues were also deliberated at length.

The salient points that emerged from the meeting are listed below.

- Invention of gene editing technology is a great leap forward in biological science and has immense potential for addressing human ailments (particularly genetic disorders), improvement of crops, farm animals and fish, and control of pests of crop plants and pests transmitting diseases in animals and humans.
- India should take urgent steps to gain technical expertise, acquire/develop biological/genetic resources to undertake research in gene editing so as to gain confidence and improve/adapt it to address problems relevant to the country.
- Considering the limited experimental evidence of the technology in terms of its efficiency, off-target effects, effects over generations and under different genetic backgrounds, a cautious approach to on-ground application of technology is advisable.
- The major crops and potential traits for improvement through gene editing technology were reviewed. The criteria for prioritization were also discussed. Genes responsible for anti-nutrients, allergens, ripening and susceptibility to pests and pathogens, particularly viruses were short-listed as targets for gene editing. It was emphasized that work should be initiated in carefully chosen crops (including annual seed propagated and clonally propagated crops) in select laboratories, and a complete end-to-end linking should be built to ensure stringent evaluation of products in an efficient and transparent manner.
- Similarly, priorities in animal/livestock sector and fisheries were presented. Considering the challenge of developing products for field use, it was considered that research should be initially targeted to perfect the technology in a few chosen animal/fish systems. The scope could be widened later after gaining confidence about efficacy, consistency, broad applicability and absence of undesired effects.
- Applications of genome editing technology to address human health were elaborated. Work on germ-line modification was ruled out at present. However, it was stressed that research work employing gene editing should be undertaken for understanding etiopathogenesis. Likewise, research work on non-germline gene editing for therapeutic use to treat genetic disorders was considered highly relevant. In particular, it was emphasized that monogenic traits such as sickle cell disease, hemophilia, β-thalassemia, liver disorders, Huntington's chorea, Duchenne muscular dystrophy, etc. which have well established genetic basis should be accorded priority.
- Control of vectors, especially mosquitoes that carry malaria, dengue, chikungunya, etc. is an area that is highly relevant to India. Considering the significant progress made internationally in this area, it was stressed that India should seriously consider assessing and evaluating the new vector control technologies and start groundwork to undertake research to address the concerns being raised about its environmental consequences and long-term effects.
- The house was informed of the steps already initiated by DBT, ICMR and ICAR to explore the use of gene editing technologies. Similarly, the moves made by agencies tasked with technology regulation, such as DBT, RCGM and GEAC were shared.
- Based on the above, the following initiatives were suggested to promote technology development and innovation:

(i) Funding – Special projects in the area of agriculture, animal sciences, fisheries and human health may be fast-tracked with appropriate collaborations.
(ii) Training/human resource development – A select set of scientists should be sent for training in leading international laboratories for a brief period (six months to one year), and should be tasked to work in the same area upon return.
(iii) Infrastructure development – A few special containment facilities according to requirement should be set up to undertake research in government institutes.
(iv) Explore public–private partnership on a case-by-case basis, where demonstrated strength is evident in the private sector.
(v) Foster inter-ministerial consultation and partnership programmes.
(vi) Identify regions/islands and environments for testing gene drives.

- Genome editing has raised questions as to how the products would be treated from the regulatory viewpoint, because changes effected through genome editing would in many cases be akin to natural mutations. It was clarified that according to the existing rules in India, the gene edited products fall under the regulated material and hence will have to undergo mandatory biosafety testing. Many considered that this will delay product development, add unnecessary cost and thereby will be a deterrent. It was suggested that a suitable subcategory of genetically modified products could be recognized and the rules be suitably amended to accommodate the new class.
- Public awareness: Based on the past experience with transgenic technology, it was emphasized that government agencies and scientists should be actively involved in educating policy-makers and general public about the new gene editing technology. This will not only help in dispelling doubts and build confidence, but also promote informed debate about the possible hazards and strategies to address the concerns.
- It was decided that a select group of crop specialists, biotechnologists, including funding agencies should be asked to prepare a list of crops and traits for funding for proof-of-concept projects. A similar approach was suggested for project formulation in animal sciences, fisheries and human health sciences.

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