green solvents explained supercritical fluids that can act as green solvent for CO_2. He described the hydrogenation process for its conversion into formic acid.

Advancements are being made increasingly for energy storage applications in graphene-based metal compounds. Advanced studies being made in Yeungnam University, Korea on metal oxide-graphene based nanocomposites for application in lithium–ion batteries and super capacitors were presented by Jae Jin Shim. He said flexible supercapacitor electrode materials made of polymer graphene oxide composites are finding applications in smart wearable devices. S. Sahoo from his team described research in super-capacitor applications. Z. Liu (Peking University) gave a perspective of the many uses of high quality graphene powders and described its unique properties as super graphene glass (SGG) for 'smart windows', antifogging glass in automobiles and as biosensors, among others.

Graphene which comprises a single layer of carbon atoms arranged in a honeycomb lattice, is the thinnest and strongest material known. China is having the highest number of patents on this wonder material, also seen as future replacement of silicon in electronics. A Graphene Industrial Park exists in China with a vision to develop rapidly growing uses in super-capacitor and energy storage applications.

There were interesting presentations on dye-sensitized solar cells, nanotechnology, conversion of biomass into biofuels and efforts made by Biomass Industries Confederation (Malaysia) to utilize them and to promote sustainable development of biomass industry. S. Bhattacharya (Indian Association for the Cultivation of Science, Kolkata) presented multifarious facets of research in creation of molecular gel nanostructures for applications. The symposium also covered biomedical and bimolecular interactions' frontline research in green chemistry. Computational booster of protein structures in living beings for enhanced drug delivery was presented by H. Jiang (Shanghai Institute of Materia Medica, China). NMR spectroscopy of molecular interactions in bio-systems viz. blood plasma and cells for disease detection and remedial actions was described by M. Liu (Wuhan Institute of Physics and Mathematics).

Another important topic covered in the symposium was toxicity caused by nanomaterials and nanoparticles in the atmosphere. Smaller particles cause highest damage to body organs, and need to be investigated said Y. Zhao (National Center for Nanoscience and Technology). On the other hand various toxic and non-toxic pollutants such as CO_2 and other greenhouse gases cause threat of global warming and climate change. In India coal is a dominant energy resource, meeting almost 70% of our energy needs. In China extensive research is being pursued on topics such as CO_2 conversion, green solvents and graphene development. Only glimpses are presented here. Looking at India's strengths in these areas and our Science and Technology co-operations with China, I suggest that the time is ripe to develop science diplomacy with China on carbon science and technology for public good. The experts could delineate specific areas to find out solutions not only in climate change space, but also to channelize scientific research towards green chemistry.

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MEETING REPORT

Monitoring the spread and management of *Tuta absoluta**

The leafminer is a native of South America and it was first described from the specimens collected in Peru in 1917. It belongs to the family Gelechiidae, that includes other important agricultural pests such as the potato tuber moth (*Phthorimaea operculella*), pink bollworm (*Pectinosphora gossypiella*), tomato pinworm (*Keiferia lycopersicella*) and Guatemalan potato moth (*Tecia solanivora*).

In 2006, *T. absoluta* was accidentally introduced to Spain from Chile and by 2009 it had spread to most of the European countries and crossed the Mediterranean Sea, reaching North African countries. By 2011, it had invaded countries in the Middle East and by 2014, it had crossed the Arabian Sea and established in the Pune area of India. In May 2016, it was recorded in some parts of Bangladesh and Nepal, along with Uzbekistan, Afghanistan and Tajikistan. In Africa, it has already invaded eastern and southern Africa, and some countries in western Africa.

This pest is capable of causing total crop loss unless control measures are instituted. Its preferred host is tomato, but it can also attack brinjal, potato, pepper and tobacco, and can develop on solanaceous weeds successfully.

The symposium began with a presentation by Rangaswamy Muniappan (Feed the Future Innovation Lab for Integrated Pest Management (IPM IL)), a program funded by USAID and managed by Virginia Tech. He gave an overview of the workshops conducted by the IPM IL program in various countries in Africa and Asia and explained that their objective was to create awareness of *T. absoluta* before its invasion, and to discuss ways to manage this pest if it shows up. The IPM IL has conducted over a dozen such workshops, reaching scientists, farmers and policy makers in more than 40 countries. A member of the BioControl Research Laboratories in Bengaluru attended one of these workshops in Addis Ababa, Ethiopia in December 2013, and based on what she learned, the company prepared *T. absoluta* pheromone lures and traps. These traps were used for monitoring the arrival of *T. absoluta* in India, and once the pest did arrive, the

*A report of the symposium on the 'Global Spread and Management of the South American Tomato leafminer, *Tuta absoluta*' held on 27 September 2016 at the International Congress of Entomology in Orlando, Florida, USA.

traps were also used to monitor its spread. This helped with suppression of the pest population in the infested fields in combination with other technologies.

Following Muniappan's presentation, Antonio Biondi (University of Catania, Italy) illustrated several basic aspects related to the pest origin, taxonomy, biology, damage and spread of *T. absoluta*. He noted that *T. absoluta* completes its life cycle in three weeks in a tropical climate, and it can overwinter in temperate climates and is capable of reproducing parthenogenetically. *T. absoluta* can also develop resistance to insecticides within a short period after repeated applications.

The next two talks focused on modeling the dynamics of *T. absoluta*. Abhijin Adiga (Biocomplexity Institute at Virginia Tech) explained the need for taking into account the human influence in the rapid spread. He emphasized the need for modeling trade, travel, greenhouse production, border interception, along with ecological and biological factors. Madhav Marathe of the same institute made a case for applying big-data analytics and high-performance computing methods in modeling the spread of invasive species. He demonstrated how state-of-the-art methods used to model the spread of human diseases take into account human mobility and urban infrastructures. There is an urgent need for such approaches in modeling *T. absoluta* noting the strong evidence for human-mediated dispersal. For example, it has crossed seas such as the Mediterranean and Arabian within a short period of time. He discussed his institute's experience with techniques used in modeling human diseases like Ebola and Zika and the importance of applying those to *T. absoluta* modeling.

Joseph Vorgetts (United States Department of Agriculture – Animal and Plant Health Services (USDA-APHIS)) reviewed different regulations instituted by his agency to prevent accidental introduction of *T. absoluta.* These involve removal of calix and pedicel from the fruits before packing them in boxes for export into the United States from the *T. absoluta*-infested countries. Harry Bottenberg (United States Department of Agriculture – Foreign Agriculture Service (assigned to the United States Agency for International Development (USAID)) provided an account of the recent detection of *T. absoluta* in Afghanistan and central Asian countries, particularly Uzbekistan. He emphasized the need for regional and global collaboration in management of this pest, as well as other invasive outbreak pests and diseases, as expertise available in this region is limited.

Ramasamy Asokan (ICAR-Indian Institute of Horticultural Research, Bengaluru) described the establishment and spread of *T. absoluta* in the western and southern states of India, and the efforts to identify the pathway of its spread within the country. He argued that the spread within India is through trade and transportation of infested fruits. Shoki Al-Dobai (Food and Agricultural Organization (FAO) regional office in Cairo, Egypt) narrated *T. absoluta*'s invasion of north African and Middle Eastern countries and the efforts of his office in assisting these countries on management aspects. Serigne Sylla of Biopass Lab in Senegal gave a presentation on the spread of *T. absoluta* in Senegal and its neighboring countries in West Africa. His talk also considered the role of alternative hosts of *T. absoluta* such as brinjal, sweet pepper, potato, etc. in aiding its establishment during seasons when tomato is not grown in this region. Findings on the bio-ecology of this invasive pest will be helpful to decision-makers in developing appropriate surveillance and sustainable management strategies.

The ratified recommendations for fighting the spread of *T. absoluta* are as follows:

- Enhance communication and collaboration between countries and regional organizations on *T. absoluta* management. (i) Develop a global network for *T. absoluta* (modeling project led by Virginia Tech's Biocomplexity Institute) including an international roster of scientists working on *T. absoluta*; (ii) Consolidate *T. absoluta* information on the IPM Innovation Lab website; (iii) Organize regional and international meetings on *T. absoluta* monitoring and management; (iv) Prepare a video or other media resources to show *T. absoluta* symptoms, management practices, etc. and disseminate it widely.
- Exercise a concerted effort to identify specific and effective agents for classical biological control of *T. absoluta* in the pest native range.
- Explore the occurrence and availability of nuclear polyhedrosis viruses (NPVs) and baculoviruses for *T. absoluta*.
- Encourage research on insecticide resistance management for *T. absoluta*.
- Encourage research on identifying and testing locally available natural substances (e.g. botanicals) active against *T. absoluta.*
- Consider host–plant resistance option for *T. absoluta* management – World Vegetable Center has a resistant germplasm that could be shared with interested institutions.
- Prepare a global Pesticide Evaluation Report and Safer Use Action Plan (PERSUAP) for *T. absoluta*.
- Encourage donor agencies to support *T. absoluta* management programs on a global scale.

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