DBT-TDNBC-DEAKIN–RESEARCH NETWORK ACROSS CONTINENTS FOR LEARNING AND INNOVATION (DTD-RNA) NEWSLETTER

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MESSAGE FROM DR PUSHPLATA SINGH, DTD-RNA INVESTIGATOR

Nanotechnology, the Great Beginning

The agricultural sector is vital to the Indian economy, although its share of the economy has decreased over the past 50 years. In recent decades, India has made significant advances in agricultural production through introduction of high- yield and climate resilient varieties with improved land and water management systems.

At present the production is resource-intensive, which has raised serious sustainability issues. Among the many scientific advancements, nanotechnology (NT) has been identified as a potential technology for reviving the agriculture and food industry and can improve the livelihood of the poor. Ensuring food security in developing countries is highly challenging due to low productivity of the agriculture sector, degradation of natural resources, high post-harvesting losses, less or no value addition, and high population growth. Researchers are striving to adopt newer technologies to narrow the food demand gap. Nanotechnology is one of the promising technologies that could improve agricultural productivity via nanofertilizers, use of efficient herbicides and pesticides, soil feature regulation, wastewater management, and pathogen detection.

Yet, further investigation is required to solve the safety and health risks associated with the technology. The use of nanotechnology for enhanced crop productivity can be a viable strategy for farmers, especially for crops growing in poor soil in exigencies, according to scientists globally. In addition to basal application, seed treatment and foliar applications are two means of application of nanofertilizers, which may prove very beneficial. Nanofertilizers also hold potential for reviving malnourished crops or crops grown on poor soil. The technology can be used to 'dress up' or treat seeds and roots for higher productivity for smart agriculture and can be executed with minimal

resources. There is a steadily growing appreciation of the integral importance of soil life in agricultural sustainability, including plant-symbiotic associations. Climate-smart and sustainable agriculture, conceiving agriculture to be resistant and resilient to a changing climate while keeping it viable in the long term, is probably the best solution. The role of soil biota and particularly arbuscular mycorrhizal (AM) fungi in this new agriculture is believed to be of paramount importance. However, the large nutrient pools and the microbiota of subsoils are rarely considered in the equation.

At TDNBC, we explore the potential contributions of biologicals-subsoil AM fungi and biogenic nano-agroinputs as putative means for reduced and more efficient fertilization, carbon sequestration, and reduction in greenhouse gas emissions from agriculture. The idea is to prepare ourselves with future agro-productivity tools, which can be executed with minimal resources.

COVID-19 pandemic has taken scientists back to the drawing board – to design futuristic strategies that are sustainable for agriculture sectors. To meet the future needs of a growing human population and to achieve food security in the context of climate change, food production will likely need to increase, while at the same time minimizing adverse environmental impact and we need to develop appropriate bio-technologies.

India started a National Nanotechnology Mission more than 15 years ago, and the technology has found huge applications in the agriculture sector, the backbone of the Indian economy. "The application of nano fertilizer is one approach to restore the sustainability of the soil alongside the agronomical benefits over and above otherwise achieved by conventional fertilizers". Nanotechnology supports the Indian agricultural market to develop products and processes with higher efficiency and lower costs. With the

increasing scope to commercialize this technology, the Indian government in 2019 proposed a set of guidelines to regulate and maintain the quality and safety of the products and processes. "While nanotechnology has high potential, the safety of its use for humans, animals, and the environment remains a concern. These regulations will oversee the use and spread of hundreds of nano-agri input products (NAIP) and nano-agriproducts (NAP), which have been circulating in the Indian market for some years now, to prevent nanoparticle toxicity in humans and the environment.

Capacity building for effective and well-functioning evaluation and regulatory systems also require human and institutional capacity at various levels. This quarter, we conducted one E winter Scho ol and two hands-on training under the DTD RNA network for knowledge sharing on varied topics related to biotechnology and nanobiotechnology.

E- Winter School on Advanced Applications of Nanotechnology for Food and Environment conducted" on 15th February, 2022

The rapid development of nanotechnology has facilitated the transformations of traditional food and agriculture sectors, particularly the invention of smart and active packaging, nanosensors, nanopesticides and nanofertilizers. Numerous novel nanomaterials have been developed for improving food quality and safety, crop growth, and monitoring environmental conditions.

The TERI-Deakin Nanobiotechnology Centre conducted an e-winter school (online mode) on the "Advanced Applications of Nanotechnology for Food and Environment" on 15th February 2022. The intense one-day program aimed to promote research perspective and impart transformative educational experience to students, young researchers and industrial participants. The winter school included five different themes on theory and practical sessions. In Session I, the experts shared the existing state of the art on nanomaterials, the challenges involved in the synthesis, characterization, and their applications in agriculture. Session II was based upon 'natural biodegradable polymer based nano-composites'. The invited talks were focused on the extraction of cellulosic materials from agro-waste and their applications in different areas. Session III was based on 'nanomaterials for rapid detection and food sensors' where portable nanosensing devices' design and application aspects were discussed. In particular, the Session focused on the portable and onsite nanosensors developments for food contaminants, pathogens, and other toxicants and their validation priorities, such as sensitivity, specificity, and precision. Session IV was based on developing food pigments from algae with improved bioavailability and stability for applications in the food industry. An invited talk was delivered on 'food preservation using novel nanofibers' in Session V. The speaker discussed the development of green polymeric nanofibers and their utilization in food packaging and preservations via incorporations of active biomolecules. Various experimental videos were also shown during the Winter School to understand better the topics discussed above. Through participatory learning experiences facilitated by multidisciplinary faculty-student interactions, interactive lectures, and innovative learning methods, the program helped the participants explore numerous opportunities in the said areas.

TERI-Deakin Nanobiotechnology Centre (TDNBC) organized Instructor - led live hands-on training modules and Lecture Series for imparting training/ skill development of the scientific community, industries, and other stakeholders having interest in nanobiotechnology.

The first HANDS ON TRAINING MODULE (Offline): Instructor-led live hands-on-training conducted and lecture delivered on the "Synthesis and Characterization of Nanomaterials".

Nanotechnology is a promising science with wide applications from cosmetics, food products, clothing, and household appliances to fuel catalyst, disease treatment, and renewable energies. Nanotechnology is also being applied to various industrial and purification processes by interfacing the nanomaterials with biological molecules or structures, "green technology" to enhance environmental sustainability, and "renewable energy" to develop new ways to capture and store and transfer energy. The TERI-Deakin Nanobiotechnology Centre (TDNBC) in collaboration with the Department of Biotechnology, Government of India hosted an in-person instructor-led live hands-on-training program to share the knowledge of synthesis and characterization of nanomaterials. The training sessions were held on February 22, 2022 at TDNBC, Gurugram. Nanotechnology constitutes one of the many critical aspects of the contemporary trends of science and advanced technologies globally. TDNBC is one of the pioneer institutes working in this area. The said training modules were unique learning propositions to the participants and aim at equipping them with the evolving concepts, tools, practices, perspectives and approaches in nanotechnology. These modules also strive to develop a sound knowledge base, collaborative analysis and ability to appreciate varied views of a vibrant group of mixed (academia and industry) participants. The training pedagogies in different modules were aptly aligned to their specific needs and foster more effective comprehension through participative learning. The interdisciplinary faculty at TDNBC, offering these programs, was a perfect blend of knowledge, experience and training skills.

The Second Instructor-led live hands-on-training conducted on Quality Control of Arbuscular Mycorrhizal Bio-fertilizers

Bio-fertilizers based on mycorrhizal fungi represent a natural way to enrich the soil in respect of environmental balance. Arbuscular mycorrhizal fungi (AMF) are the most common symbiotic association between terrestrial plants and microorganisms, which are known to improve plants development and growth, especially under stress conditions. The potential for application of AMF in agricultures is an agro-ecological approach to allow better use of soil nutrient reserves. That receives increasing consideration for their prospective application for sustainable agriculture.

The TERI-Deakin Nanobiotechnology Centre (TDNBC) with support from Department of Biotechnology, Government of India hosted an in-person instructor-led live hands-on-training program to share systematic and practical knowledge about 'Quality Control of Arbuscular Mycorrhizal Biofertilizers'. The training sessions were held on March 3, 2022 from 10:00 AM to 3:30 PM at TDNBC, Gurugram.

MESSAGE FROM

DR. J. C. TARAFDAR,

**UGC-EMERITUS PROFESSOR
FORMER ICAR EMERITUS SCIENTIST
FORMER PRINCIPAL SCIENTIST AND NATIONAL FELLOW CENTRAL ARID ZONE RESEARCH INSTITUTE,JODHPUR, RAJASTHAN**

Nanotechnology applications in agriculture are gradually transforming the theoretical possibilities into the practical applications. The potential is increasing with suitable techniques and sensor being identified for precision agriculture, natural resource management, early detection of pathogens, contaminants in food products, efficient delivery systems and use efficiency for fertilizers and pesticides. Nanotechnology shows their potential to become major economic driving force in agriculture and benefit the consumer and farmers with no detrimental effect on the ecosystem with the recommended doses of application. For example, the major benefit of shifting from chemical fertilizer to nanofertilizer are their low requirements and more nutrient use efficiency, low cost and higher crop yield moreover encourage enzyme release to mobilize plant nutrients as well as plant physiological activities. Nanotechnology approach also found to be effective in global horticultural production in economically and environmentally sustainable manner. Nanoparticles also can be used as nanobioformulations. The formulations containing one or more beneficial microorganisms after blending of required nanoparticles to enhance soil productivity. Nanobioformulations can be helpful to enhance the stability of biofertilizers with respect to desiccation, heat and UV inactivation. It can also solve some limitations of biofertilizers such as ease to handling, enhanced stability, protection against oxidation, retention of volatile ingredients, taste making, consecutive delivery of multiple active ingredients etc. It can also very well be use against plant biotic and abiotic stress as well as soil health management. As a result of large surface to volume ratio, there is more interaction between atoms in intermixed with materials in nanoparticles, which leads to increased strength and increased heat resistance. They have also high catalytic activity and can be used as effective catalyst of the plant and microbial metabolism. There is enormous scope to use nanomaterial in every sphere of agriculture which starts from the seed treatment to grain storage. Nanomaterials can also be introduced in or on the food itself. But, it is necessary to create international standards for nanotechnology and in addition special international organizations in the area of nanotechnologies to reduce national differences in assessing of nanotechnologies and risk governance practices. Nanotechnology can pose significant risks to food production, food distribution and healthcare systems that are poorly understood and are particularly important to a small country that can ill afford to mount the research effort required to manage the risks that are likely to emerge with the accelerating global development of nanotechnology. For these purposes it is necessary to create the research infrastructure for toxicology and risk assessment. In aspects of nanotechnology study courses it is necessary to define what kind of skills and knowledge are needed in a small, agricultural country to take advantage of nanotechnology and to manage risks that are likely to emerge with increasing commercialization of nanotechnology. Ultimately, nanotechnology innovations may enable the agricultural industry to precisely control and improve production by reducing the disease incidence and increasing the nutrient availability. I am sure that collaborations build within DTD-RNA will help to resolve many challenges in agriculture with the help of nanotechnology tools; they are devoted to serve global communities with the knowledge and the products for the future.

MESSAGE FROM

CRISTINA ARIMANY NARDI,

PROJECT MANAGER OF STRATEGIC INITIATIVES INSTITUTE OF BIOENGINEERING OF CATALONIA, BARCELONA NANOMED, SPAIN

Nanomedicine seeks solutions against rare diseases

Coinciding with February 28th, the world day for rare diseases, experts invited by the Nanomed Spain platform and the Sant Joan de Déu Research Institute (IRSJD) presented the latest advances in nanomedicine against rare diseases. agriculture with the help of nanotechnology tools; they are devoted to serve global communities with the knowledge and the products for the future.

During the current pandemic, nanomedicine has shown itself to be a key player in offering diagnostic and therapeutic solutions against COVID-19 with, for example, antigen tests or vaccines. But this is not its only field of application: the fight against rare diseases could also benefit from nanomedicine. Rare diseases, also known as orphan diseases, are pathologies or disorders that affect a small part of the population, but which, as a whole, can affect up to 8% of the world's population. These diseases, which generally have a genetic component, manifest themselves in a series of particular symptoms being very difficult to diagnose. They are therefore diseases that separately affect a small number of people, but which have a global impact on society. That is why nanomedicine, the discipline that uses the advantages of materials on a scale up to a million times smaller than the thickness of a hair, is also looking for solutions.

At Nano Rare Diseases Day 2022, an event organized by Nanomed Spain, the Spanish Nanomedicine Platform coordinated by IBEC, and the Institut de Recerca Sant Joan de Déu, experts from hospitals, companies and research centers presented the novelties that nanomedicine offers against three of these rare diseases: Duchenne muscular dystrophy, cystic fibrosis and Fabry disease.

Cystic fibrosis: when every breath is harder to take

Cystic fibrosis is an inherited disease of the mucous and sweat glands. It mainly affects the lungs, pancreas, liver, intestines, sinuses and sexual organs. This disease causes the mucus to be thick and sticky and to become "plugged" in the lungs, causing breathing problems and facilitating the growth of bacteria. This can lead to repeated lung infections and lung damage.

The symptoms and severity of cystic fibrosis can vary. Some people have serious problems from birth. Others may have a milder type of the disease that doesn't show up until adolescence or early adulthood. Sometimes the disease begins with few symptoms that can increase over the time.

In an attempt to expose more aspects of the disease, Jordi Costa, Pulmonologist at Hospital Sant Joan de Déu, presented this 28th of February, the "New therapeutic approaches in Cystic Fibrosis" from a clinical perspective. On the other hand, the biologist and Group Leader at the Institute of Bioengineering of Catalonia (IBEC), Professor Eduard Torrents, presented "Nanotechnology for the diagnosis and treatment of biofilms that produce chronic infections in Cystic Fibrosis".

The big problem with cystic fibrosis is the formation of thin sheets, called biofilms, which make it difficult to treat with antibiotics. Nanomedicine is helping us find better treatments.

In our laboratory, we have developed the "Biofilmchip", a microfluidic system where we can cultivate biofilms obtained directly from patients, and we can treat them with the antimicrobial therapy that we believe is most appropriate. In addition, we can identify how many bacterial types are in each biofilm.

Eduard Torrents, group leader at IBEC

Muscular dystrophy: when the body stops responding

Duchenne muscular dystrophy is a rapidly worsening form of muscular dystrophy caused by a defective gene for dystrophin (a protein found in muscles). However, it often occurs in people whose families do not have a known history of this condition.

The disease most often affects boys because of the way the disease is inherited. In order to meet this challenge, nanomedicine tries to find solutions. To present the latest advances in nanomedicine for muscular dystrophy, two experts working in Barcelona presented their research in this field.

Nano Rare Diseases Day

During this event, the latest innovations in Nanomedicine are presented each year, with topics ranging from early diagnosis, controlled release of drugs or the development of new therapies.

During the conference, experts in Nanomedicine from different fields -research, business, clinical practice, health authorities, patients, etc.- presented the latest advances and give us the opportunity to discover the generator of progress that Nanomedicine means for health as a creator of new opportunities in the diagnosis and treatment of rare diseases.

In this year's edition, experts from the Sant Joan de Déu Hospital, the Sant Joan de Déu Research Institute (IRSJD), the Institute for Bioengineering of Catalonia (IBEC), the «Duchenne Parent Project Spain», the Sarrià Chemical Institute and the company Nanomol Technologies, have met at the ***Nano Rare Diseases Day 2022.***

MESSAGE FROM

HIMADRI B BOHIDAR,

SENIOR FELLOW
NATIONAL CENTER FOR EXCELLENCE IN AGRICULTURAL NANOTECHNOLOGY
TERI-DEAKIN NANOBIOTECHNOLOGY CENTER, GURUGRAM, INDIA

Nanotechnology: A defining technology for the 21st Century

Japanese scientist Norio Taniguchi coined the word "Nanotechnology" in the year 1974. However, the field did not take off until Eric Drexler provided the much-needed scientific impetus to it during the 1980s. Due interdisciplinarity, it has grown leaps and bounds touching almost all aspects of basic and applied science and technology. Today it is an important enabling technology platform to solve many of the challenges the mankind is facing, or about to face in the forthcoming decades. A bird's eye view of the development of this field in the last two-decades is schematically depicted in figure 1. Following wider integration of nanotechnology with various branches of science and engineering particularly in the last decade (2011-2020), the field is projected to vertically scale up to make deeper and value added inroads into the domains of health care, agriculture, energy, environment, manufacturing, electronics, and transport sector etc. This vision is based on the robust nanotechnology ecosystem that exists today.

One of the major problems facing the mankind pertains to the issue of climate change which will adversely affect the well-being of everyone on the Earth. Global mean surface temperature is projected to rise by 1.5–2 °C within the next 40–50 years that will make the Earth unfit to live in the next century. The erratic weather pattern so caused is bound to have a profound effect directly on the agriculture due to unpredictable and disturbed pattern of precipitation. According to the recent projections made by the United Nations, the world's population is expected to increase from 7.7 to 9.7 billion by 2050, and to peak at nearly 11 billion by around 2100. This scenario would lead to a significant increase in the demand for all types of resources and services, especially the agricultural products, medical care, sanitation, energy, and above all, for more irrigation water. Clearly, the brunt of these problems will be faced by the population living in the less developed geographical areas of the World.

The solutions are projected to be found through effective intervention of nanoscience using the evolving nanotechnology landscape. The multifunctional role of nanotechnology is ideally suited to address the climate change mitigation. Scientists have deeply explored a wide variety on nanomaterials including nano silica and zeolites, nanoporous carbonaceous materials, nanocomposites, metal-organic frameworks, and hybrid nanostructures that have shown promise in the sequestration and storage of greenhouse gases, and the generation, storage and transport of clean energy fuels. While nanocatalysts aid in the efficient combustion of fuels reducing greenhouse gas emission, the nanocomposites used as light weight materials in transportation will reduce fossil fuel consumption and global warming. Nano-lubricants will help in the reduction of friction in engines and, thus cutting down the consumption of fuel considerably which in turn lower the mission of carbon dioxide. Tailor-made nano fertilizers, pesticides and hydrogel coated seeds will aid sustainable farming of the future by improving the soil and plant health leading to higher crop yield.

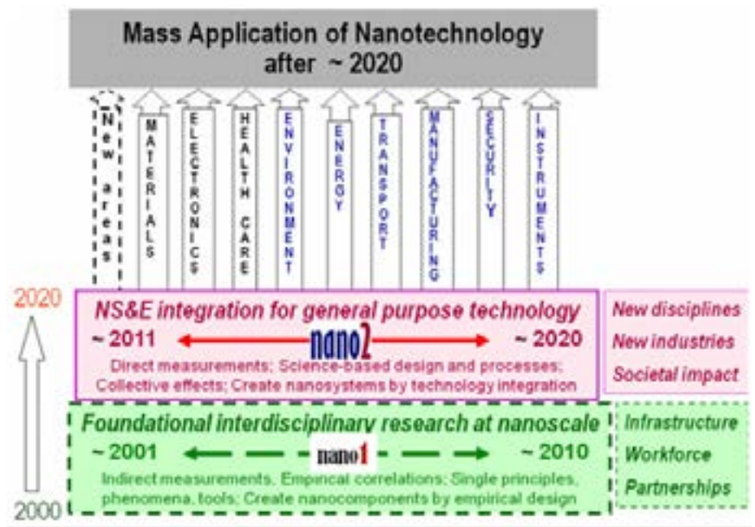


Figure 1: General outlook of the nanotechnology platform in the past two-decades. (Source: WTEC Panel Report on Nanotechnology Research Directions for Societal Needs 2020).

Notwithstanding the aforesaid possibilities that is sure to make the world a better place to live there are identifiable challenges too. Nanoscience, which defines the underlying nature of forces and interactions on which the edifice of nanotechnology is built is poorly understood even now. The key issues of equilibrium thermodynamics, chemical kinetics, atomic and molecular relaxations, interfacial effects, charge and mass transfer, diffusion, and tribology operating at the nanoscale, which in turn defines self-assembly, material heterogeneity and phase stability requires to be established on a solid foundation at the molecular level on systems that do not span beyond 100 nm in space. Clearly, out of box conceptualization and formulation of nanoscience is called for. Simply put we need to develop a clear understanding of structure-property correlation in nanomaterials which will help us in the design and development of smarter and tailored nanostructures with predictive attributes. Further, we must walk the complete nano-path which is defined as the following: (i) Synthesis of nanomaterials, (ii) their comprehensive characterization, (iii) application, and (iv) finally, their safe disposal. This requires the long-time life cycle assessment of various nanomaterials in the environment. Any scale-up to mass produce nanomaterials must also adopt a protocol of green chemistry with a small carbon footprint. Fortunately, none of these challenges seem unsurmountable.

Managing an emerging technology requires specific approaches, and considering its potential to fundamentally transform science, industry, and commerce, and of its broad societal implications, nanotechnology is here to stay as the defining technology of the 21st century.

MESSAGE FROM

DR. SHRUTI SHUKLA,

SENIOR SCIENTIST, TERI-DEAKIN NANOBIOTECHNOLOY CENTRE DTD-RNA CO-INVESTIGATOR

Bionanotechnology, as a tool for incorporation of biological molecules into nanoartifacts, is gaining more and more importance in the field of SAFE FOOD INSURITY. Nanotechnology is having an impact on several aspects of food science, from how food is grown to how it is packaged. Food companies are developing nanomaterials that will make a difference not only in the taste of food, but also in food safety, and the health benefits that food delivers. In current years, the surveys are speaking about the lack of consumer awareness, government guidelines, policies, and detection methods for nanotechnology risk assessment that warrants better understanding of nanomaterial-based toxicity characterization, regulatory processes and food applicable guidelines. Safe nanomaterials have potential to lead qualitative and quantitative production of healthier, safer, and high-quality functional foods which are perishable or semi-perishable in nature.

Nanobiotechnology institutions of India (IITs, IISER, IISC, JNCSR, VIT, INST, TDNBC-TERI etc) making consistent efforts for developing nanosensors that can detect bacteria and other contaminates/adulterants, such as salmonella, at a packaging plant. In addition to this, we from TDNBC-TERI team are also on our progression path to contribute scientific inputs in the field of water and environmental sensing strategies, which will allow for frequent testing at a much lower cost than sending samples to a lab for costly analysis. This point-of-packaging testing, if conducted properly, has the potential to dramatically reduce the chance of contaminated food reaching grocery store shelves. Research is also being conducted to develop nanocapsules containing nutrients that would be released when nanosensors detect a vitamin deficiency in the body system. Basically, this research could result in a super vitamin storage system in the human body that delivers the nutrients when you need them.

Although tremendous efforts have been put into the treatment of infectious diseases to prevent epidemics and mortality, it is still one of the major health care issues that have a profound impact on humankind. Therefore, the development of specific, sensitive, accurate, rapid, low-cost, and easy-to-use diagnostic tools is still in urgent demand. Nanodiagnostics, defined as the application of nanotechnology to medical diagnostics, can offer many unique opportunities for more successful and efficient diagnosis and treatment for infectious diseases.

Another development being perused is a network of nanosensors and dispensers used throughout the farm field. The sensors recognize when a plant needs nutrients or water, before there is any sign that the plant is deficient. The dispensers then release fertilizer, nutrients, or water as needed, optimizing the growth of each plant in the field one by one.

Nanotechnology is opening up new horizons in almost all scientific and technological fields. Among these, applications of nanotechnologies are expected to bring extended benefits and add value to the food and food-related industries through the whole food chain, from production to processing, safety, packaging, transportation, storage and delivery. The promising DTD-RNA networking programme originated from TERI-Deakin Nanobiotechnology Research Centre (TDNBC) with support of DBT, India aims to promote a research network at highly specialised and next-generation nano-science platform.

E-WINTER SCHOOL ON

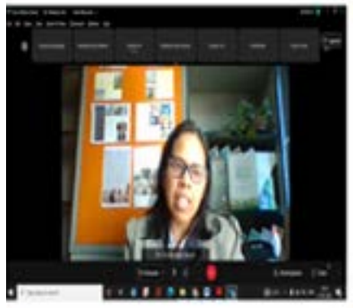
"ADVANCED APPLICATIONS OF NANOTECHNOLOGY FOR FOOD AND ENVIRONMENT"

Globally, about 1.3 billion metric tons of food is wasted annually, and consumer food waste accounts for ~40% of the food system's carbon footprint. So, what is the way out? How can we minimize food waste? In pre-historic times, based on the climatic conditions, sun and snow were two natural ways to treat food and preserve it. Our immediate ancestors were fond of drying, smoking, salting, pickling, and fermentation.Most of these techniques started accidentally and with generations of trials and errors they are more refined and established.

We still follow these techniques in modern times. However, more demand has been expected by the inquisitive minds in this regard, such as extending the shelf-life to months/years through smart polymeric packaging and monitoring the food quality using sensors that can be integrated easily with the packaging materials. For example, microalgae-based food colors are in huge demand in the market due to their synergistic functional effects on foods and human health; however, the issues with stability and shelf-life are still hampering their nutraceutical commercialization in terms of cost economics. These issues could be minimized with the intervention of nanotechnology for enhancing the stability of food colors extracted from various microalgal strains.

Let's talk about a few examples involving nanomaterials? Nanocomposites from waste biomass utilization can make the packaging material less permeable to atmospheric conditions and thus improve the shelf-life. Nanosensors can be designed to have better sensitivity and specificity to detect various pathogens and toxins. These capabilities can, in turn, inform the consumers about the freshness level of the food. The possibilities are enormous and the avenues are open for exploration. Similarly, nanotechnology is being used to improve environmental stability. This includes cleaning up of existing pollution, and improving manufacturing methods using 'green' technology. In this regard, TERI-Deakin Nanobiotechnology Centre (TDNBC), Gurugram, India in association with the Department of Biotechnology, Government of India under "DBT-TDNBC-DEAKIN-Research Network" for learning and innovation (DTD-RNA)" across the continents, organized "Winter School Program" on "Advanced Applications of Nanotechnology for Food and Environment" on 15th February, 2022.

The winter school was aimed to spread advanced knowledge on the practical applicability of various nanomaterials for food, agriculture and environmental safety. Young researchers, students, and technocrats participated in this program to learn new insights in the thematic area.



The program began with the welcome address by Dr. Pushplata Singh, Director, TERI- Deakin Nanobiotechnology Centre, Gurugram, followed by an introductory virtual tour of TERI and TDNBC nano research achievements and facilities. The program was moderated by Dr. Rita Choudhary, Dr. Mukul Dubey, Dr. Palash Kumar Manna and Dr. Shruti Shukla, TDNBC, TERI.

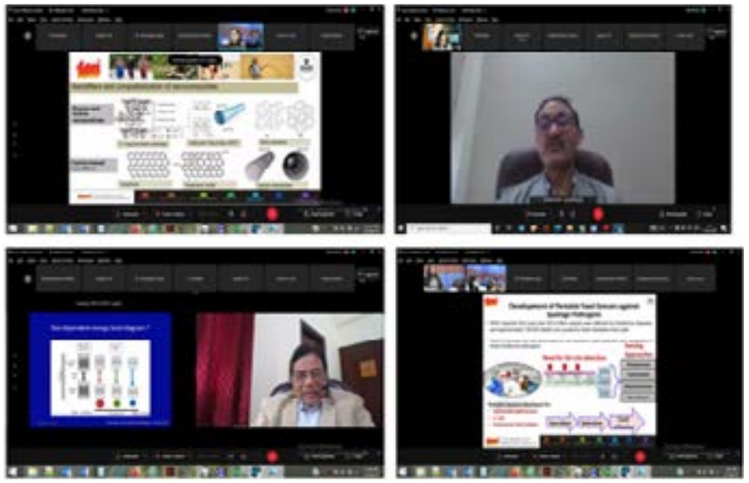
The program had five thematic talks on the applications of nanomaterials and their utilization in Food, Agriculture, and Environmental sectors. The scientific session started with a keynote talk by renowned Indian nano-agriculture scientist, Prof. Tarafdar (ICAR Emeritus Scientist) who briefly explained various aspects of nanomaterials and nanofertilizers for better agricultural productivity.

Prof. Himadari Bohidar (TDNBC, TERI) delivered an insightful talk on the synthesis and applications of nanomaterials in different areas. He explained the challenges one may face during the synthesis and characterization of such nanomaterials.

The session continued with other thematic talks delivered by Dr. Ruchi Agarwal (Senior Scientist, TDNBC-TERI, Gurugram), where she shared the knowledge for developing agrowaste-based natural biodegradable polymeric nanocomposites by covering zero waste policy and "Net Zero" carbon emission.

Advanced aspects of nanomaterial utilization for developing on-site diagnostic tools for the food and agriculture sectors were discussed by Dr. Shruti Shukla (Senior Scientist, TDNBC-TERI, Gurugram). She also highlighted the importance of nanomaterials in detecting food freshness and spoilage levels by using nano-sensing devices and smart packaging systems.

The large scale production of microalgae suffers from shelf-life and stability issues. Dr. Amrit Preet Kaur Minhas (Senior Scientist, TDNBC-TERI) shared the basic knowledge of microalgae cultivation and high-quality biomass generation for efficient



extraction of algal pigment. She also addressed the strategies of nano-interventions for enhanced stability, bioavailability and shelf-life of these algal-based food pigments.

The last thematic lecture was presented by Dr. Ashutosh Upadhyay (Dean, NIFTEM, Sonipat, India) on nanofibers and their applications in improving the food preservation techniques by developing various nanoformulations for reducing food spoilage and post-harvest losses. He also discussed the food safety issues and how nanomaterials can help in improving the issues of biodegradable, smart & active nano-packagings.

After each session, an interactive Q&A session was held. The E-winter school platform was attended by more than 120 participants across the globe.

HANDS ON TRAINING (OFFLINE) ON

"NANOMATERIALS SYNTHESIS, CHARACTERIZATION AND APPLICATION IN SEED COATING FOR CLIMATE SMART AGRICULTURE"

Nanomaterials are composed of nanoscale structures, usually achieved via multiple physical, chemical and biological processes. They acquire unique electronic, optical, mechanical, magnetic and catalytic properties that cannot be achieved without their nano-architecture. Such nanomaterials provide unprecedented opportunities for tuning their properties in a very broad range of application sectors, such as agriculture, food, environment, and energy. With the increasing importance of nanomaterials in fundamental research and technological applications, it is desirable that researchers would be aware of various unexpected challenges associated with reproducible synthesis and characterization of nanomaterials, including the difficulties of maintaining desired materials properties during handling and processing. It is equally valuable for researchers to understand how characterization approaches (surface and otherwise) can help to minimize synthesis surprises and to determine how materials and their properties change in different environments.

Amongst numerous applications, nanaomaterials could provide possibilities to coat various seeds in the form of pellet or film and improve the quality of germination (hence, the yield) and shelf life. In real applications, different nanoparticulate systems have shown promise to increase the biological activity and reduce the toxicity of herbicides, fungicides, and insecticides. These nano-seed coating systems can promote sustained release of loaded materials, convey active agents to specific targets, and enhance bioavailability at the target organism. In brief, advanced nanomaterials provide unprecedented opportunities to tune their properties for desired applications.

In this regard, TERI-Deakin Nanobiotechnology Centre (TDNBC), Gurugram, India in association with Department of Biotechnology, Govt. of India under "DBT-TDNBC-DEAKIN-Research Network" across continents for learning and innovation (DTD-RNA)" project organized hands on training (offline) on "Nanomaterials Synthesis, Characterization and Application in Seed coating for Climate Smart Agriculture" on 22nd February, 2022.

The hands on training module aimed to cover one of the most important scientific trends, synthesis of nanomaterials and theircharacterization for their intended applications. Young researchers, students and technocrats participated in this program to learn new insights in the said area.

The day began with the welcome address by Dr. Pushplata Singh, Director, TERI- Deakin Nanobiotechnology Centre, Gurugram, followed by an introductory virtual tour of TERI and TDNBC nanobiotechnology research achievements and facilities. The program was moderated by Dr. Shruti Shukla, TDNBC, TERI.

Training module was divided into two sessions where subject expert of nanomaterials, Dr. Palash Kumar Manna gave a detailed lecture on synthesis and characterization of various nanomaterials and how to tune them for the desired applications. The session continued with laboratory visit and hands on training by Dr. Suneeti Singh on nanomaterials synthesis and their characterization via different techniques such as DLS, Zeta potential, FTIR, and UV spectroscopy.

During the second session subject expert of seed coating, Dr. Rita Choudhary elaborated the topic by explaining advanced techniques of nano-seed coatings. She stressed on the benefits of this technique to protect seeds from microbial losses and enhancing their germination and nutrient use efficiencies. The experimental demonstration of polymeric formulations and seed coating were also carried out during the session.

After each session, an interactive Q&A session was held. The hands on training (offline) was attended by 12 participants.

HANDS ON TRAINING (OFFLINE) ON

"QUALITY CONTROL OF ARBUSCULAR MYCORRHIZAL BIOFERTILIZER"

TERI-Deakin Nanobiotechnology Centre (TDNBC), Gurugram, India in association with the Department of Biotechnology, Government of India under "DBT-TDNBC-DEAKIN-Research Network" across continents for learning and innovation (DTD-RNA)" project organized "Hands- on Training workshop for Quality Control of Arbuscular Mycorrhizal Biofertilizer" on 3rd March, 2022.

The event commenced with the introductory remarks and welcome address by Dr Palash Kumar Manna (Associate Fellow, TDNBC, TERI), followed by an introductory virtual tour of TERI and TDNBC nanobiotechnology research achievements and facilities. The programme was moderated by Dr Shruti Shukla (Fellow, TDNBC, TERI). The hands-on training module aimed to generate awareness about the quality evaluation of mycorrhizal biofertilizers by way of capacity building among the researchers, professionals and consultants working in industries. The training module included interactive sessions and discussions on various

quality parameters of products as per guidelines pertaining to the Fertilizer Control Order (FCO), Government of India and the challenges faced during assessment of formulated products.

The training module was divided into two lecture sessions each followed with hands-on training by the subject experts of mycorrhiza. Session 1 focussed on "Analysis of mycorrhiza based biofertilizers: Quality control and Challenges" with a lecture by Dr Ankit Kumar (Fellow and Area Convenor, Centre of Mycorrhizal Research, TDNBC, TERI). He discussed about the fundamentals and practical aspects of quality control analysis of the various arbuscular mycorrhizal fungi (AMF) based products available in the market. He emphasized on the major technical and technological challenges faced by Industries with respect to the regulatory requirements and the best possible measures to be adopted for regulatory compliance. This was followed by discussion on the protocol for enumeration of spores, viability assessment of spores and estimation of root colonization. Session 2 focussed on "Assessment of infectivity potential of mycorrhiza based biofertilizers" with a lecture by Dr Leena Johny (Associate Fellow, Centre of Mycorrhizal Research, TDNBC, TERI). She discussed about the various bioassays which are undertaken for the estimation of infectious fungal propagules in AMF based products and measurement of mycorrhizal colonization after a defined period of time as the data. Specific bioassay as defined in the FCO guidelines were elaborately explained to the participants followed with preliminary requisites of the AMF product before setting up the bioassays were also shared with the participants. Both the sessions were followed with hands-on training by the expert speakers which included the isolation of mycorrhizal spores from the formulated product followed by microscopic analysis to understand the differentiation between AMF spores and the carrier components associated in the formulated product, viability assessment of spores in the products, and colonization of root as observed microscopically during data generation under bioassays. This was followed by a brief technical session via video demonstrations on step-wise quality control analysis of AMF-based formulation and raw data collection.

An overwhelming response was received in the interactive session where both industrial and academia participants raised and discussed their queries with the expert speakers and gained valuable insights.

The hands-on training was attended by 6 participants offline and 1 participant online.

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