THE ENERGY AND RESOURCES INSTITUTE

Creating Innovative Solutions for a Sustainable Future

Sustainable Agriculture Programme

Sustainable Agriculture Programme (SAP) dedicates itself towards creating innovative solutions and developing new opportunities for profitable farming and livelihoods while conserving natural resources. Our research focuses on sustainable agriculture, environment, and bioenergy by developing plant- and microbe-derived products to substantially improve crop yields, thereby reducing carbon footprint in agriculture. We extensively work on key areas aimed towards improving plant and soil health that include plant- and nano-biotechnology to develop green products like nano- and biofertilizers, superfoods, algal-based bioenergy, bioremediation, and resilient crop plants to biotic and abiotic constraints, besides enhancing their nutritional profile.

Our Focus Areas

- Development of regenerative agriculture technologies to improve soil health
- Agriculturally beneficial microbe-based formulations to reduce carbon footprints and increase yield
- Nano-agri inputs for enhancing nutrient-use efficiency and reducing GHG emission from agriculture
- Bioremediation of industrial wastelands
- Green technology-based functional materials from natural/ waste resources
- Superfoods and algal-based bioenergy from advanced bio-resources
- Climate resilience of plants through cutting-edge technologies such as trait engineering and gene editing
- Micropropagation for disease-free, high-yielding quality planting material of economically significant crops to improve farmers' income.

Solutions for Sustainable Development

- **Next-generation formulations of mycorrhizal biofertilizer:** By harnessing the mycorrhizal microbiome and synergistic, agriculturally relevant bacteria, new formulations are being developed. This led to a functionally advanced mycorrhiza biofertilizer product powered by TERI's in vitro P.E.G Technology of Performance Enhancing Green Biologicals 'Uttam Superrhiza', presently being commercialized by agro-industries.
- **Nano-nutrients and nano-fertilizers:** As an alternative to conventional chemical fertilizers, TERI has successfully developed biologically-synthesized nano-agriproducts including macronutrients, weedicides, and pesticides.

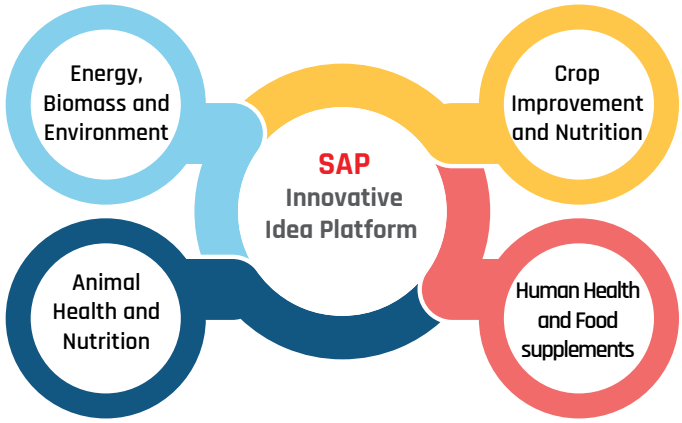
TERI and CFCL launch mycorrhiza product

Three major nano-fertilizer products, currently at the pre-commercialization stage have successfully completed bio-efficacy test using drone technology in 10 agro-climatic zones in India and 100 acres in Guyana.

- **Microalgal farming:** We have developed ecology-inspired solutions by growing algal consortia for increased algal productivity, and a tool to track nutrient stress in real-time algal cultivation system for cultivation of marine microalgae.
- **Microbial products:** Microbial pigments as natural and sustainable sources of colourants for food, cosmetics and textiles are being developed and tested.
- **Reclamation of wastelands:** Industrial waste sites including fly ash overburdens, alkali–chlor laden sites, distillery effluent discharge sites, phosphor–gypsum ponds, coal mines, red mud, saline, and arid sites are being reclaimed using selected plant species and mycorrhizal formulations.
- **Plant biotechnology:** Application of molecular markers genetic assessment and improvement of ergonomically important traits. Bioengineered rice with enhanced photosynthesis for higher yield under elevated carbon dioxide and rice capable of synthesizing its own nitrogen are being developed to suitably address climate change scenarios.
- **Micropropagation technology:** Micropropagation Technology Park with an annual capacity to produce over three million plants produces disease-free planting material for government projects, nurseries, and commercial growers as livelihood options.

Thematic Domains

Implementation of cutting-edge, transdisciplinary biotechnology, and nature-inspired solutions that harness the power of plants, microorganisms, and microbiomes for achieving agricultural and environmental sustainability through four thrust areas involving research, development, production, marketing, and livelihoods.



Agricultural biotechnology

Agricultural biotechnology drives reforms in agriculture research through adoption of technological advances, strengthening research infrastructure and human resource development in cutting-edge research. This includes plant-, microbiome- and microbe-derived products to reduce agrochemical overuse and carbon footprint, while enhancing productivity, input use efficiency, nutritional fortification, improved quality parameters, abiotic/biotic stress tolerance, input use efficiency, climate resilience and biosafety. The aim is to bring circularity in agriculture and building a framework for regenerative agriculture. Over the years, R&D projects in basic and translational research, national networks, centres of excellence, international collaborations and public–private partnerships have been accomplished. The area

has undergone a paradigm shift over the years according to evolving needs of the farmers, consumers, and markets to provide solutions in the form of varieties/technologies/products, capacity building, infrastructure creation, and knowledge generation. Technologies and products based on the next generation of mycorrhizae, microencapsulated bacteria, plant-beneficial biofilms, nano-agricultural inputs, natural food inputs, algae, improved crop varieties through application of molecular markers, reclamation and management of ecologically sensitive industrial wastelands have been developed.

Micropropagation technology park

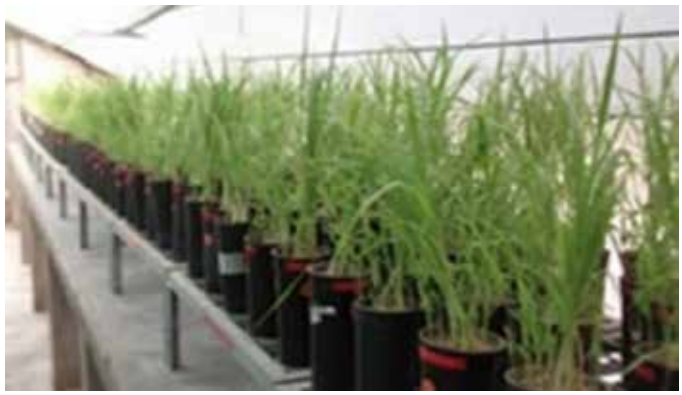
The Micropropagation Technology Park (MTP) is a pioneering initiative in mass propagation of disease-free novel germplasm of medicinal and aromatic plants, cash crops, ornamentals, fruit crops, and forest plants for smallholder farmers' livelihoods through proactive market linkages and business development. Besides producing disease-free planting material through tissue culture, MTP also provides training to start-up entrepreneurs and technical workforce for industry.

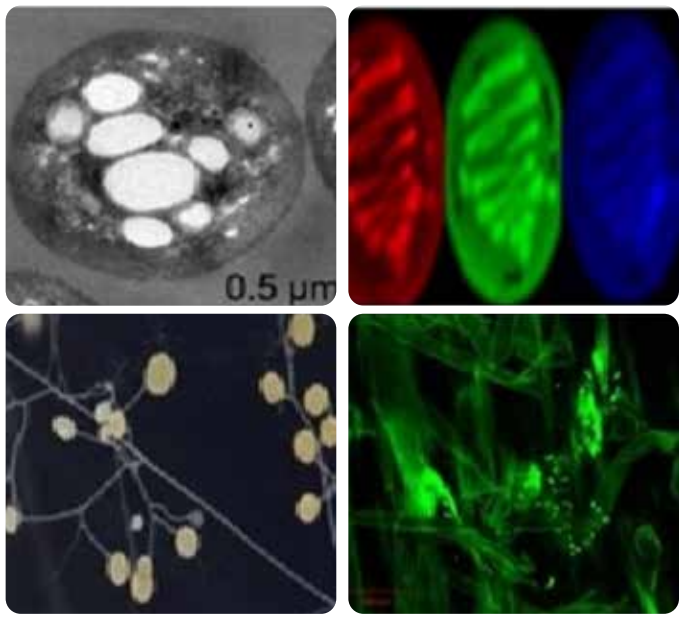
Micropropagation of plants in tissue cultures

Mycorrhiza Commercial Production

Research on mycorrhiza has successfully translated the nutrient-tapping potential of the symbiotic system and developed a technology that eventually produces mycorrhizae-based biofertilizer. The facility supports in vitro mass production to produce healthy, genetically pure, and high-quality mycorrhizal propagules for product development. More information on mycorrhiza commercial production can be accessed at: http://mycorrhizae.org.in/cmcc/.

Patented in vitro Mycorrhiza Technology allows for the bulk synthesis of high-quality, pathogen-free, live, healthy, and genetically pure fungal material. The first-of-its-kind manufacturing technology of TERI that is based on in vitro root organ cultivation and the products created at the Mycorrhiza Mass Production plant is FCO compatible with the Fertilizer Control Order, 1985 and is being commercialized through co-marketing partnerships with top pesticide and fertilizer companies. Current developments include novel products such as mycorrhizal formulations tailored to specific crops and soil microbiome components that are compatible with the farming practices for sustainable agriculture.





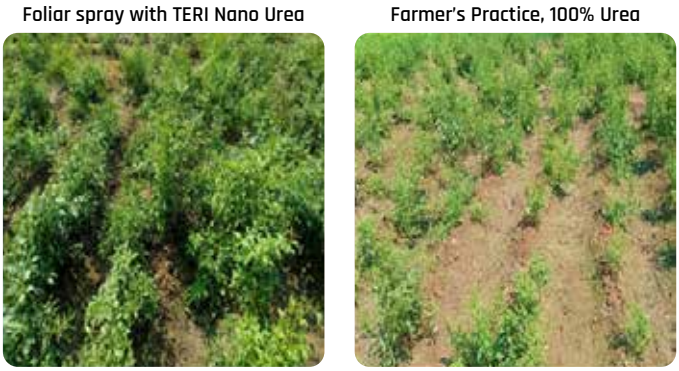
Microbes and microbe-derived products such as mycorrhiza, microbial polymers and pigments, and plant–microbe interactions

Our research-based innovation has increased corn yield by 8% while reducing reliance on fertilizers by 25%

Drone-based application of nanoDAP in a field of corn in Andhra Pradesh showed yield enhancement by 22%

Nano commercial production

Nano products are developed for commercialization using a biogenic approach instead of the commonly used chemical approaches. Microbial organisms are tuned as bio-factories for converting bulk material into nanomaterials, which generally make all nanomaterials produced by TERI and are safe by design for both human health and the environment. Nanomaterials are being developed primarily for use in agriculture in the form of nano-fertilizers, nano-pesticides, smart carriers, and other industrial applications.



Evalution of TERI Nano Urea product under drone application in Chilli

Outputs of the Sustainable Agriculture Programme are primarily aligned with major United Nations Sustainable Development Goals where besides addressing important goals like zero hunger and good health and well-being, improving soil quality and health while enriching soil biodiversity, using a rich microbial germplasm bank to develop biofertilizers and nano-agro-inputs are other important contributions.

TERI-Deakin Nano-Biotechnology Centre (TDNBC)

Our Expertise

Accomplishments

Centre of Excellence in Agrinanotechnology (CoEA)

Collaborations between DBT, TERI-Deakin Nano-Biotechnology Centre (TDNBC), and academic partners have not only resulted in the development of effective nanotechnology-based solutions for sustainable agriculture but also serve as a platform for lifecycle analysis and safety assessment of nanomaterials as per the Organization for Economic Cooperation and Development (OECD) and the National Institutes of Health, USA (NIH) guidelines. More information on CoEA can be accessed through our web portal: https://www.teriin.org/projects/coe-ncearan/.

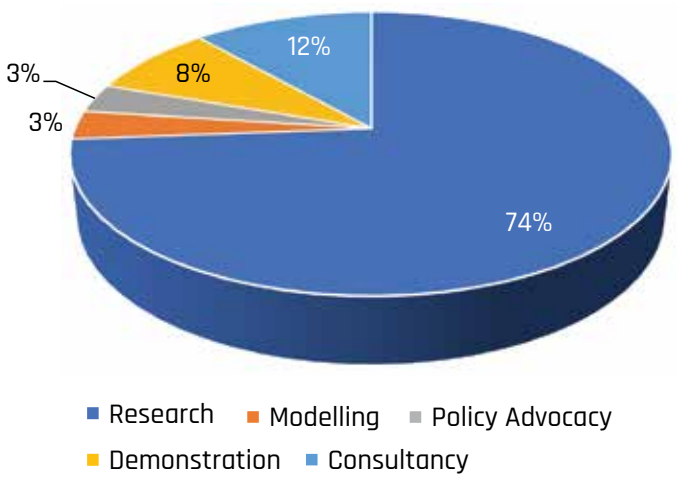
Reducing GHG emission

- Nanofertilizers developed using biological approach lead to minimal generation of chemical waste, besides 100X reduction in application rate as compared to conventional fertilizers.
- Mycorrhizal biofertilizers have superior field performance with improved plant and soil health with less use of water, besides enhancing carbon capture and soil amelioration.
- Reclamation technology for replenishment of contaminated wasteland while creating green cover with native species.

Skill development and capacity building

- TERI and TERI School of Advanced Studies along with the Deakin University Australia contributes to building capacity of research scholars and professionals in agri-biotechnology.
- Research Network Across continents for learning and innovation (DTD-RNA): In association with the Department

of Biotechnology, Government of India, TERI and Deakin University have created DBT–TDNBC–DEAKIN – Research Network across continents for learning and innovation. Workshops via both online and hands-on modes on 'nanoscience research and development' carried out under the programme have helped in capacity development of students and researchers at different levels in India and several Asian, African and European countries. More details on this can be accessed via https://tdnbc.teriin.org/index.php.



Agents of Positive Change in the Agriculture Sector

Successful agricultural transformations are accompanied by multiple benefits by creating jobs, increase farmer incomes, provide food, and nutritional security. This considers climate-smart strategies for enhanced resource use efficiency, integrating soil biodiversity, women's economic empowerment, prioritizing agricultural value chains in both food and export commodities in a limited number of crop and livestock value chains, better quality seeds and more effective fertilizers/biofertilizers, and farmers' livelihood.

Awards and Recognitions

1. Mycorrhizal technology has been recognized as one of the top 13 Innovators helping India meet its reforestation goals in 2021 by 1t.org through the Trillion Trees Initiative of The Forum of Young Global Leaders and the Global Shapers Community.
2. Hindustan Zinc Limited received CII National Award for Environmental Best Practices 2021 for successfully carrying out two projects in collaboration with TERI, including plantation of 50,000 plants in Biodiversity Park at Rajpura Dariba Mine and developing green area on the wasteland recognized as innovative environmental projects by the industry.
3. TERI and Tata Chemicals Limited (TCL) were recognized with the Marico Innovation Award in the 2010.

Key Patents

- A novel mycorrhizae-based biofertlizers consortium and Root Organ Culture (ROC)-mediated production of the same.
- Novel mycorrhizae-based biofertilizer compositions and method for mass production and formulations of the same.
- A novel vanillin-linked noble metal nanocomposite (nanoformulation) for enhancing antibiotic sensitivity against clinical isolates of *Pseudomonas* sp.
- A novel bioreactor for mass production of arbuscular mycorrhizal fungi (AMF).

Way Forward

The Sustainable Agriculture Programme aims to proactively contribute to the economic development of the agriculture-dependent community by providing products and services, environmental stewardship, and social responsibility. Hence, we continue to create cutting-edge products and technologies for new innovations while preserving and optimizing the use of natural resources.

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