Nanotechnologies in Precision Farming

1909

2009

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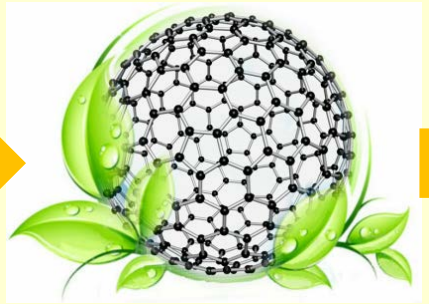
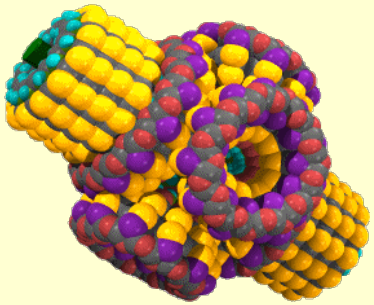
Coimbatore

NABARD

Nanotechnology For Food Security
Nano Agriculture

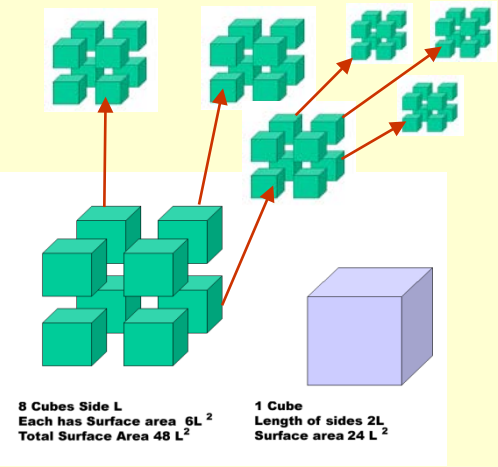
Nano Agriculture





Infuse nanotechnology concepts and principles in agricultural sciences to evolve processes and products that precisely deliver inputs in production systems that ensure food security and environmental safety

Nano = One billionth of a Metre



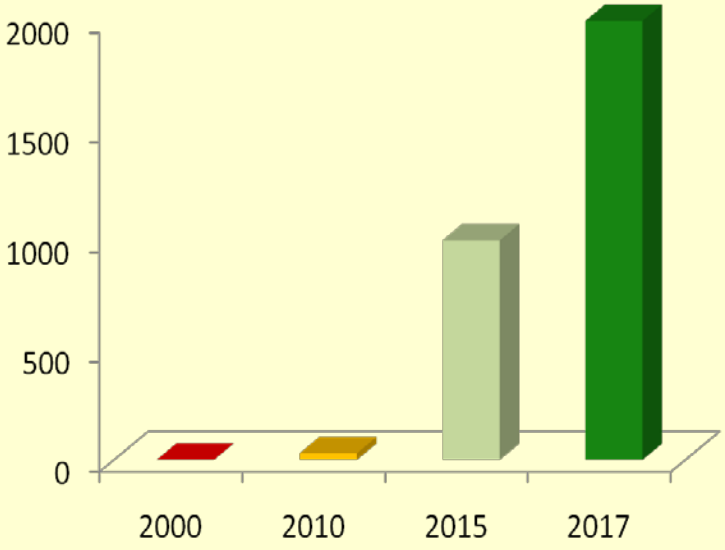
130,78,55,375

Mar. 24, 2019 at 11:30 pm

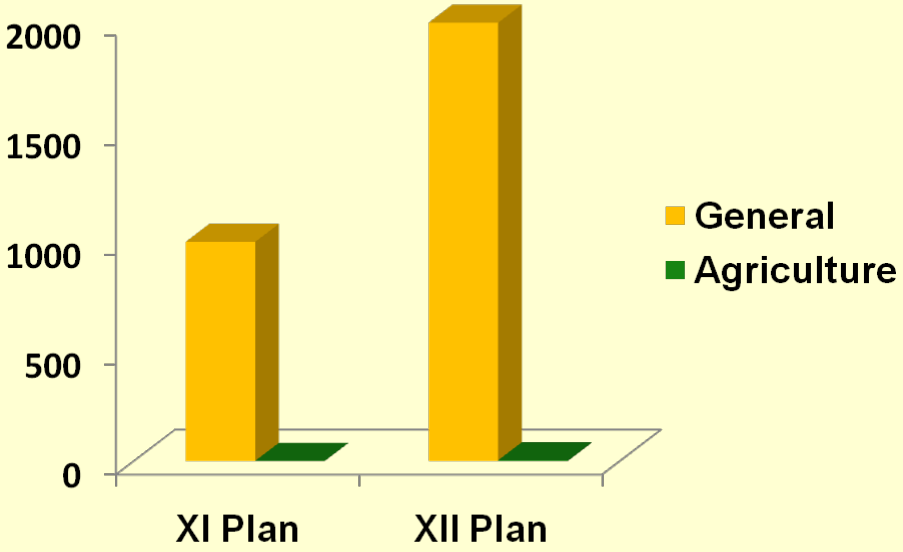
Atom-by-atom manipulation yields in précised processes and products for smart delivery of inputs

Investment in Nanotechnology

Global Investments
(USD in Billions)



Indian Investments
(Rs. In Crores)



Nanotechnology investments increased by 2000-fold increase in 17 years

India's investments had nearly doubled in the past 10 years

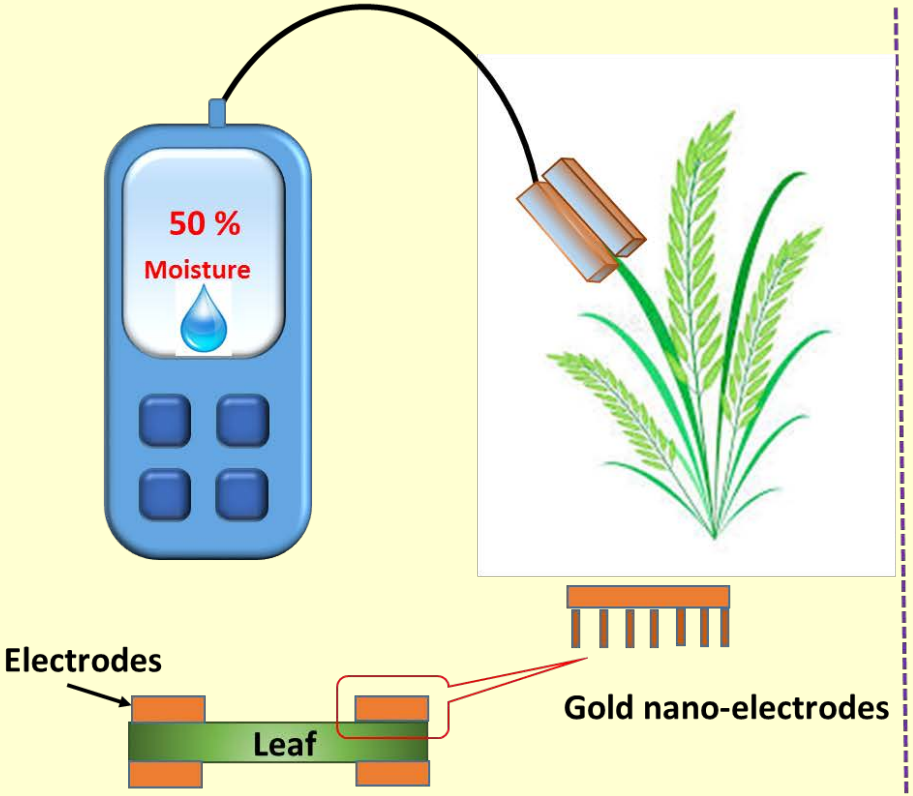
Nano in Precision Agriculture

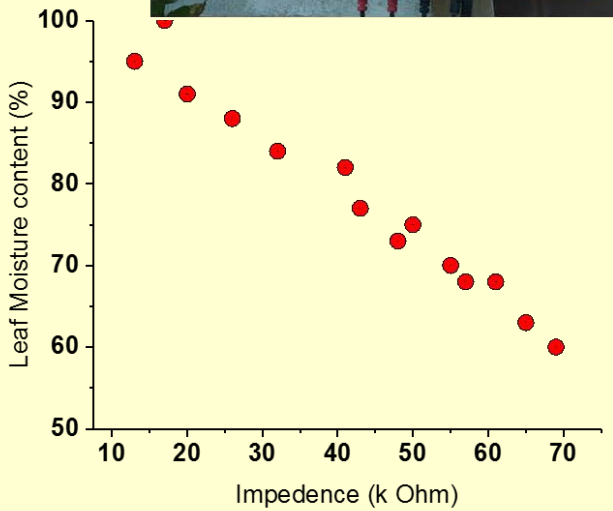
- **Timely detection of nutrient deficiencies and diseases**
- **Smart delivery of inputs in agri-food systems**
- **Nanotechnologies to minimize post-harvest losses**
- **Biosafety of nano-products**


1. Nano-Diagnostics

On-Site Detection of Leaf Moisture

Working range
50 – 90%



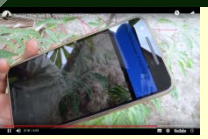


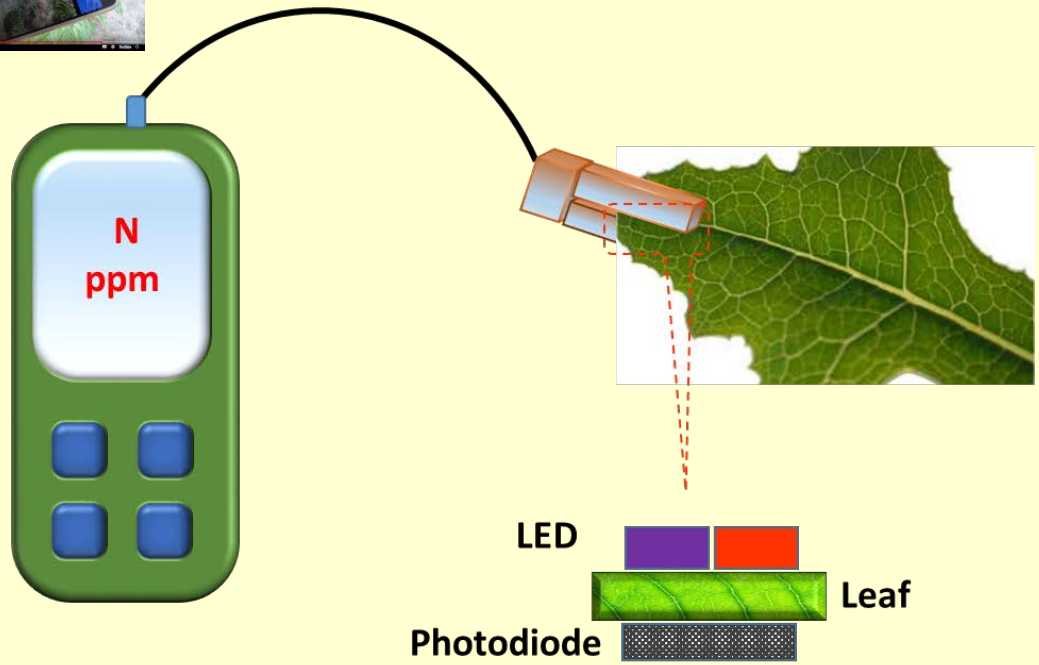
Irrigated

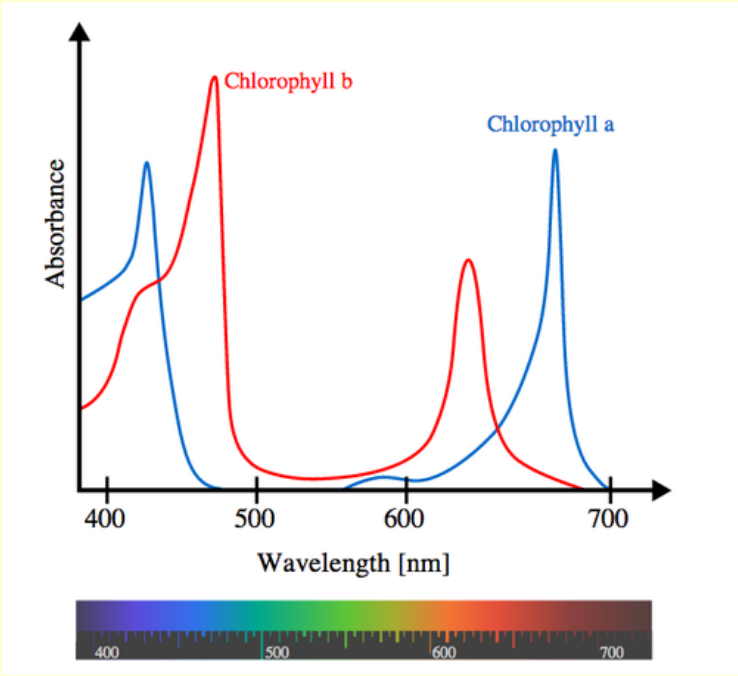
Stressed

Impedence is inversely proportional to moisture status of the leaf

Leaf Nitrogen – Optical Sensor

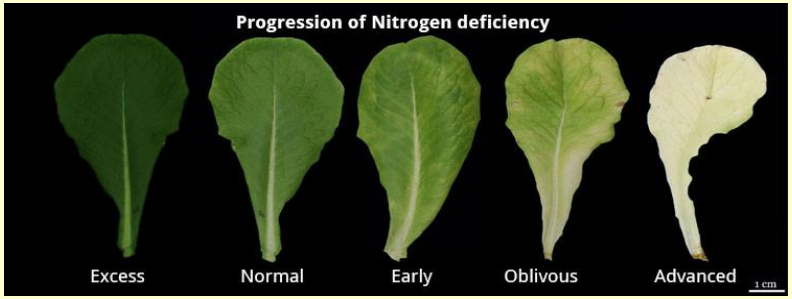






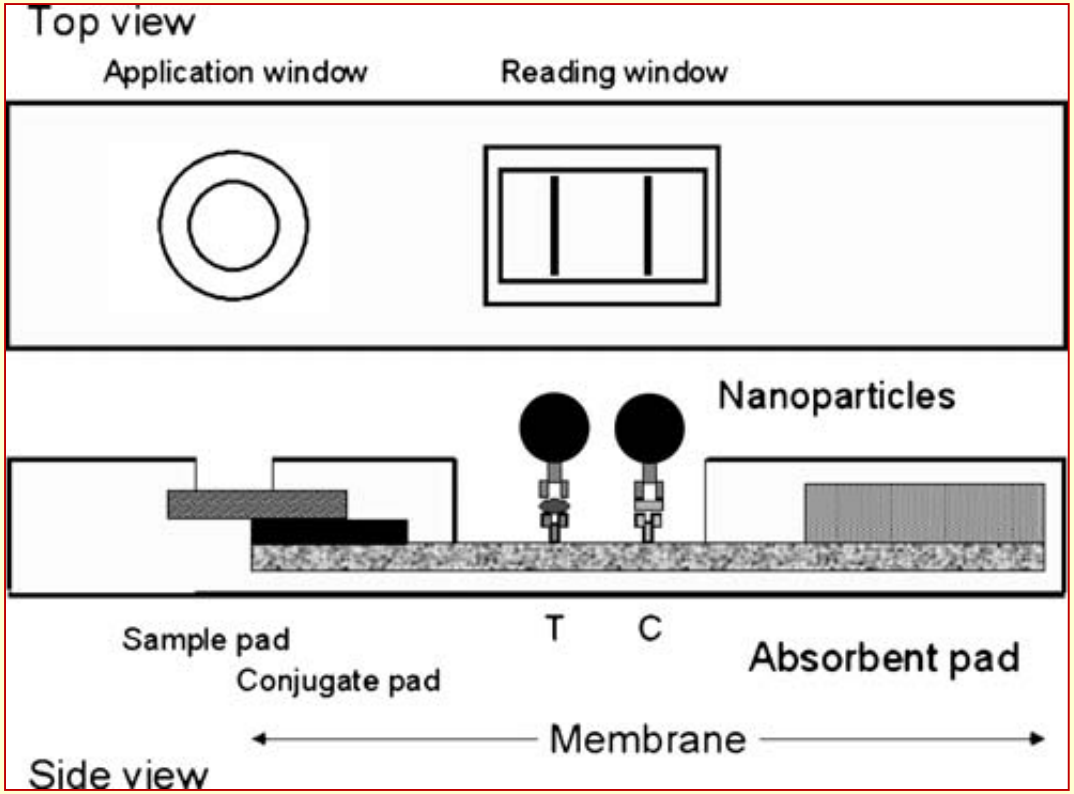
Working range
1.0 – 3.0%

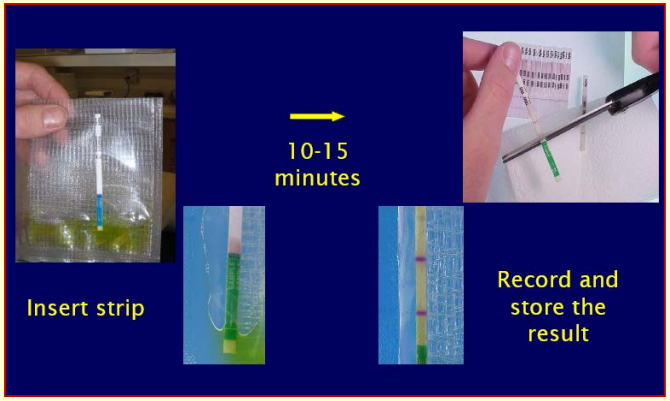
Two LEDs of specific wavelengths for Chl ‘a’ (660nm) and Chl ‘b’ (420 nm) are transmitted and the rate of absorbance is related to the N content of leaves



Early Detection of Plant Diseases

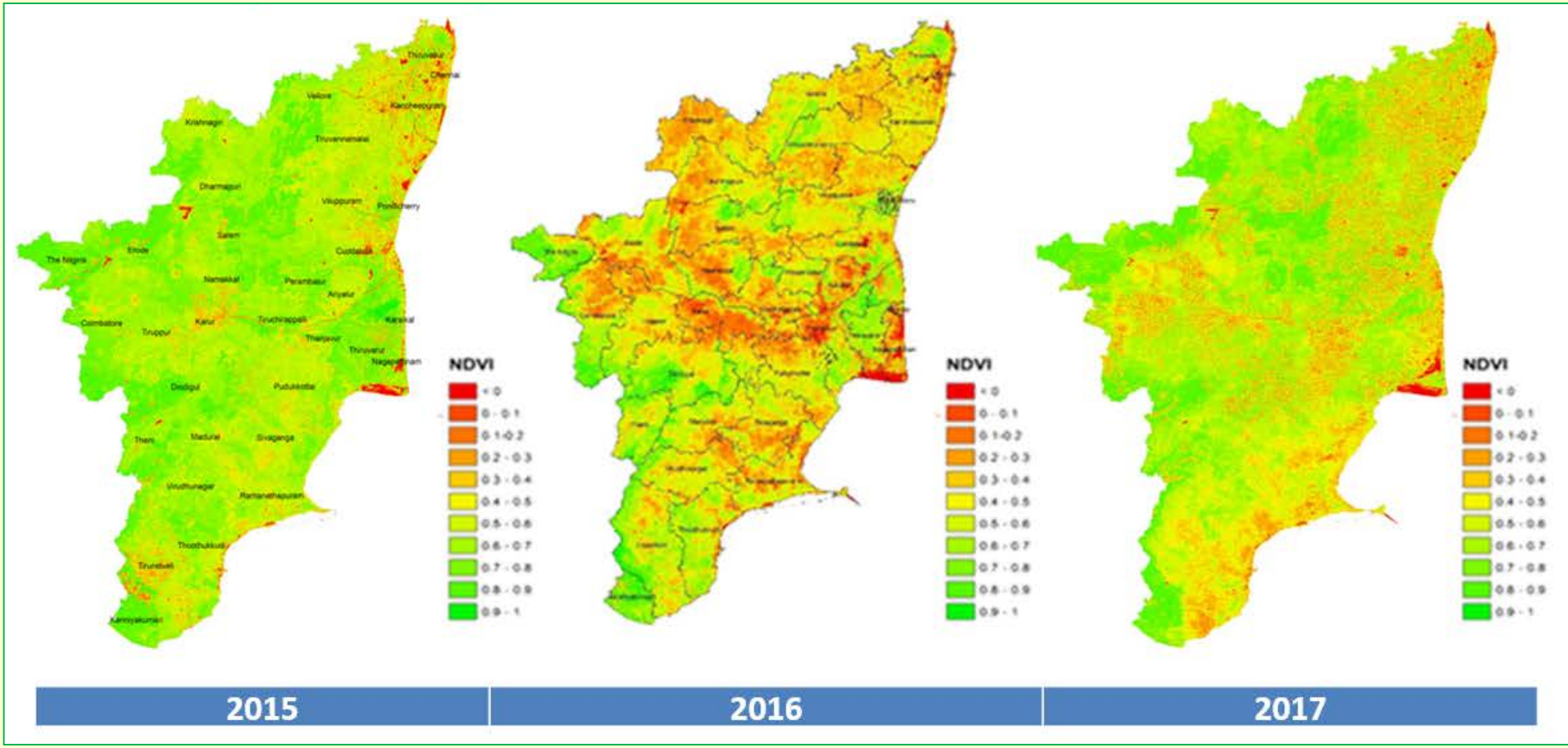
Nanotechnology utilizes chromatographic principle coupled with immunological recognition system to detect plant diseases



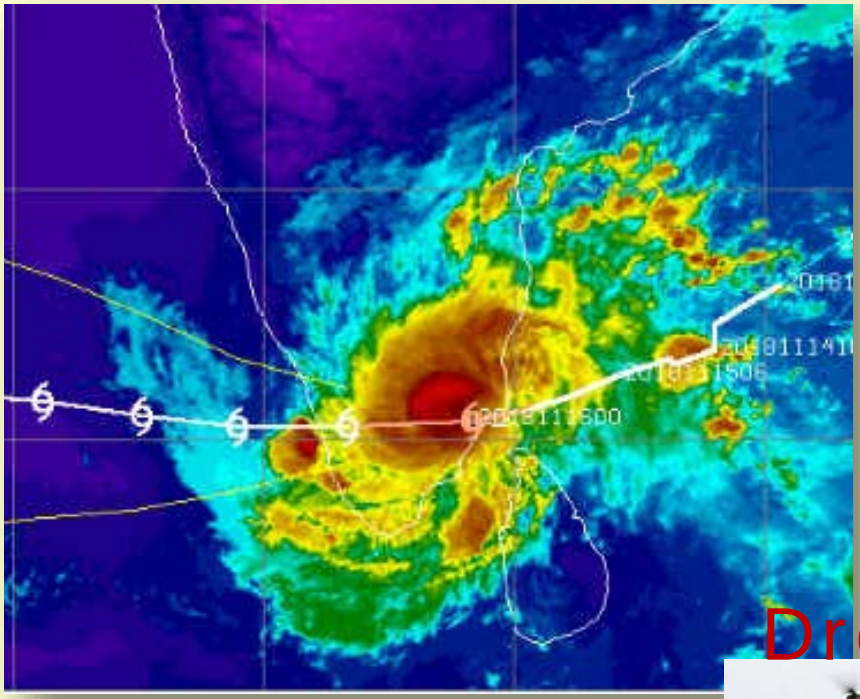


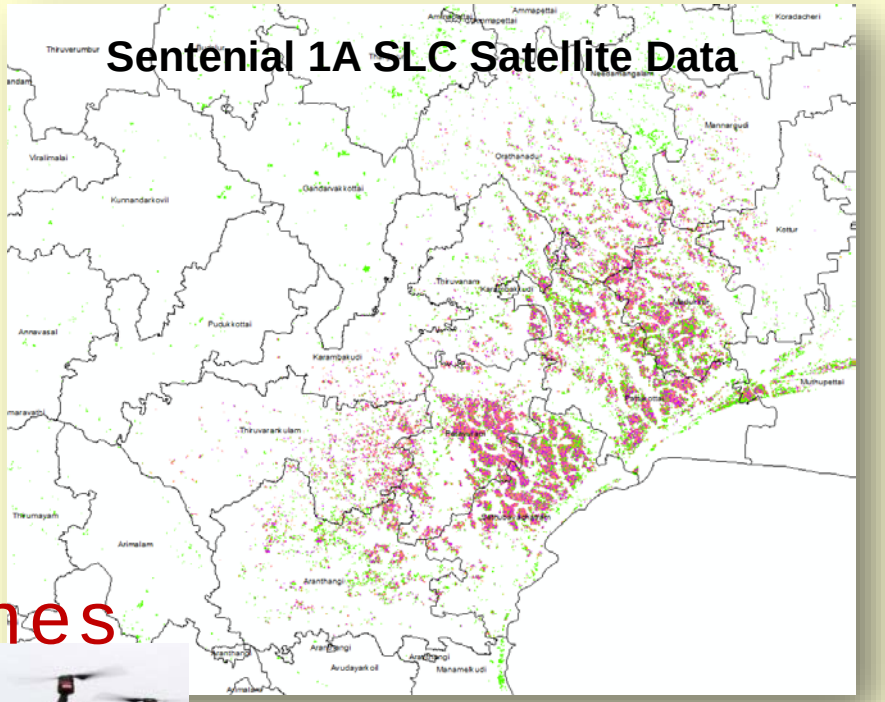
Sensitive
Rapid detection
Less analyte
Cost effective

Drought Assessment using Spectral Indices



Gaja Cyclone in Tamil Nadu





Drones

Detailed Damage Detection

Districts	Blocks	Damaged Trees
Thanjavur	Madukkur	445749
Thanjavur	Sethubavachatiram	603914
Thanjavur	Orathanadu	335941
Thanjavur	Thiruvonam	136271
Thanjavur	Pattukottai	830548
Thanjavur	Peravurani	769701
Tiruvarur	Mannargudi	75113
Tiruvarur	Thiruthuraipoondi	6128
Tiruvarur	Muthupettai	87047
Tiruvarur	Kottur	61267
Pudukottai	Thiruvarankudi	231680
Pudukottai	Karambakudi	63295
Pudukottai	Aranthangi	228269
	Total	**3874923**


2. Smart Delivery

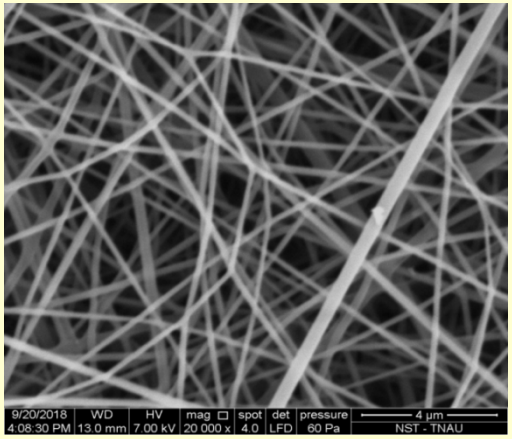
Encapsulation of Seeds

(Nano-Fibre Loaded with Nutrients)

Encapsulating Drum

Encapsulated Seeds

SEM View

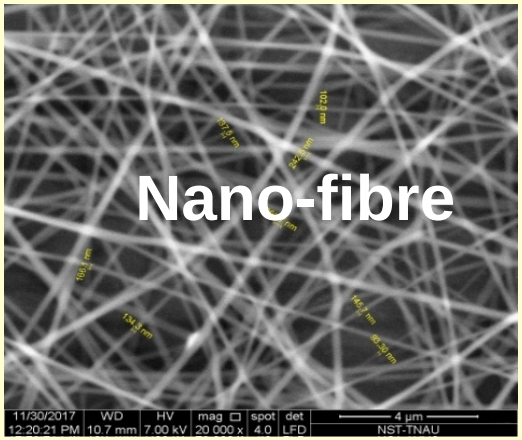


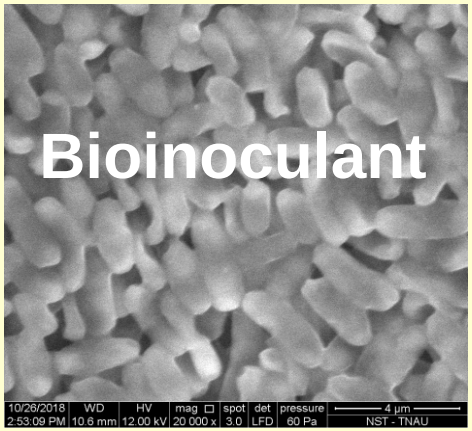
High Surface Mass Ratio

Specific Surface Area
(8000-9000 m^2 g^{-1})

Length
(> 1000 KMs)

Nanofibre Loaded with Bioinoculants





Nano-fibre can carry entire gamet of agricultural inputs

Performance of the Seedlings

Control

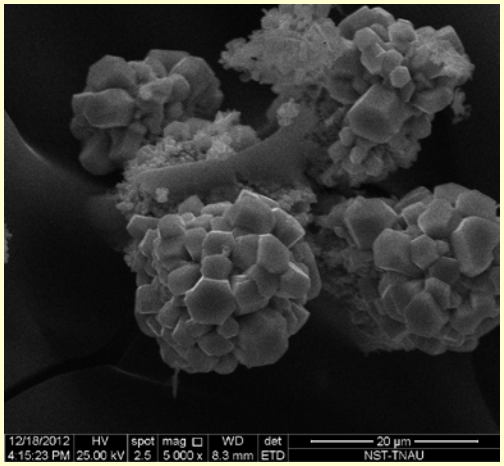
Treated

Nano-fibre with Optimal Nutrients Promote Seedling vigour

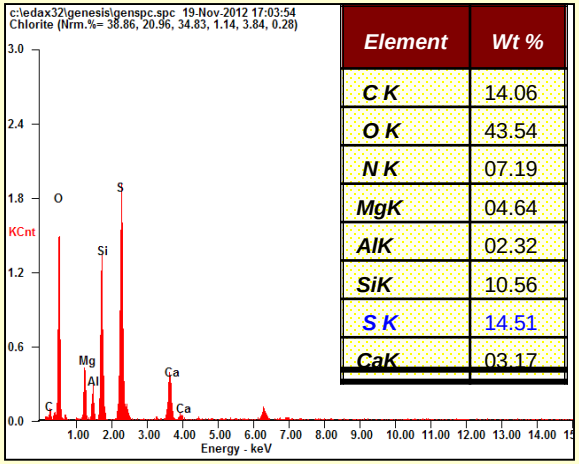
Nano-Fertilizer for Groundnut

(Thirunavukkarasu and Subramanian, 2014)

SEM image of Nano-S

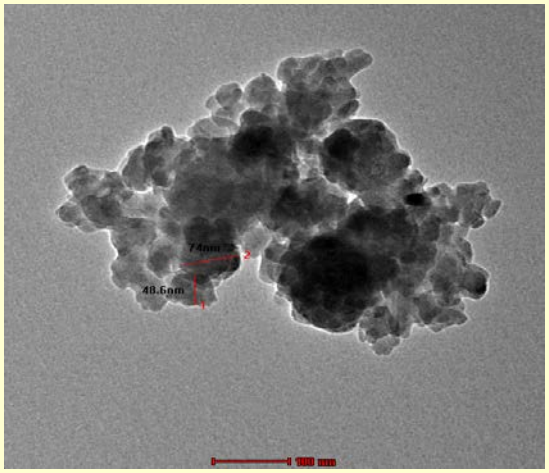


EDAX – S content

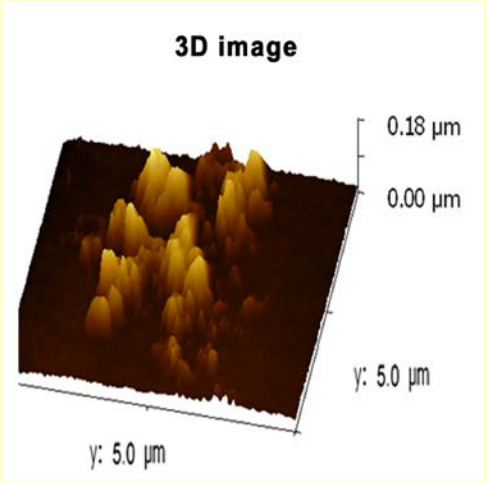


Element	Wt %
C K	14.06
O K	43.54
N K	07.19
MgK	04.64
AlK	02.32
SiK	10.56
S K	14.51
CaK	03.17

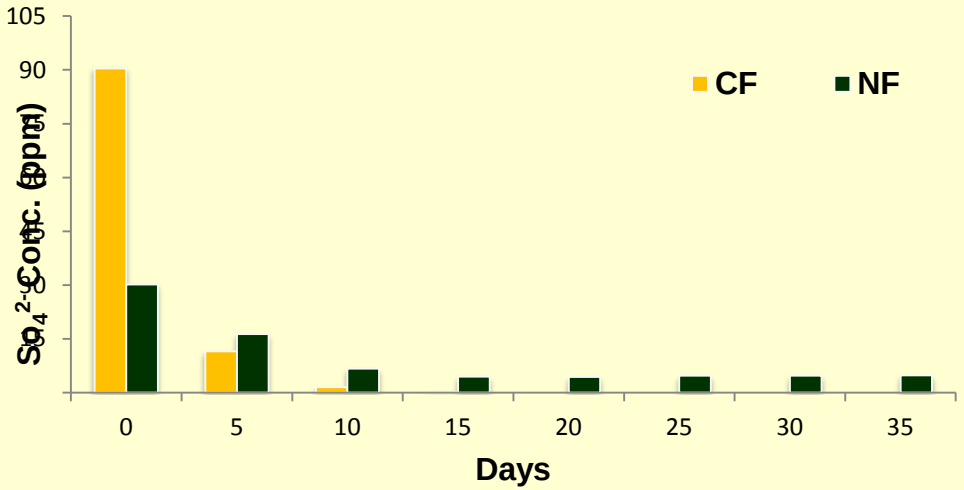
TEM Image



AFM



S Release Pattern

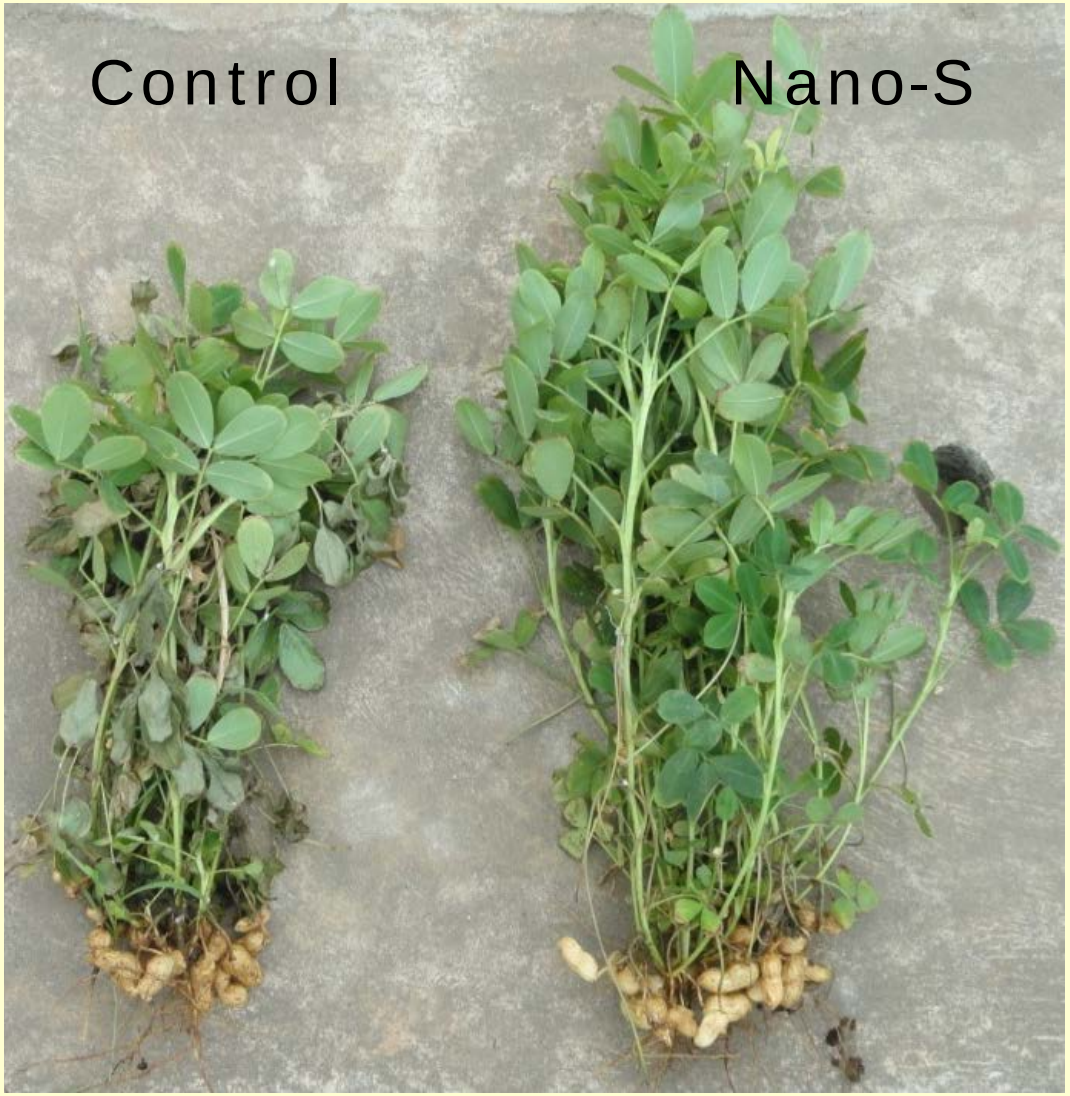


Sulphate Movement in Plant System

Element	Wt %
C K	40.73
N K	01.19
O K	45.52
MgK	06.24
AlK	00.10
S K	**0.32**
K K	01.05
CaK	04.84

Element	Wt %
N K	10.77
O K	84.73
MgK	00.55
P K	00.00
S K	**0.19**
K K	01.11
CaK	02.66

Element	Wt %
N K	01.90
O K	74.11
MgK	06.06
AlK	0.66
S K	**0.91**
K K	0.40
CaK	15.96

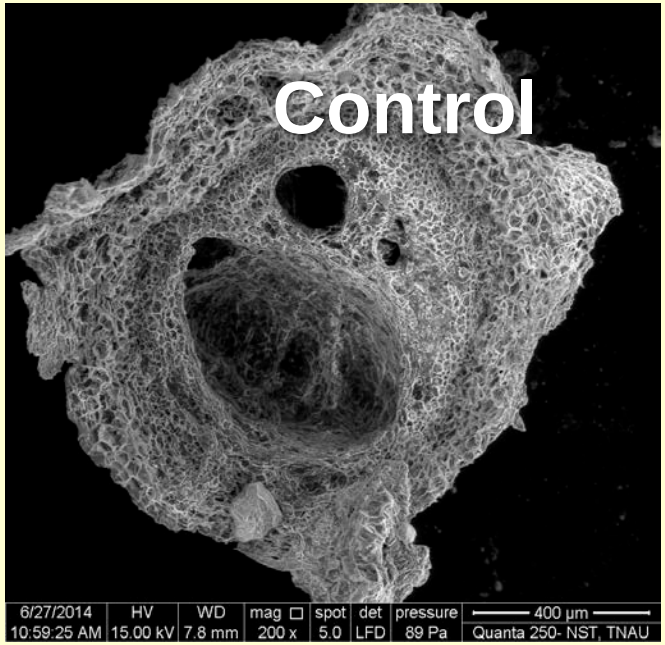


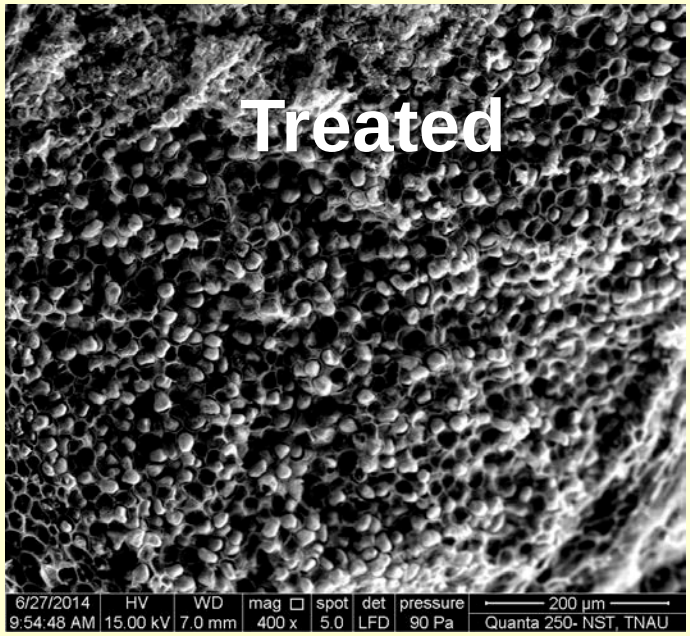
Element	Wt %
N K	04.55
O K	69.77
MgK	04.76
AlK	11.80
S K	**0.70**
K K	03.13
CaK	05.28

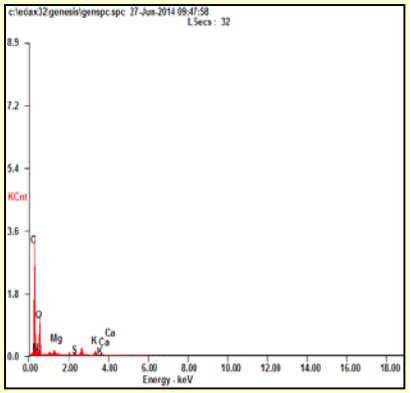
Element	Wt %
N K	02.39
O K	71.83
MgK	00.74
AlK	11.64
S K	**0.34**
K K	10.89
CaK	02.15

Element	Wt %
N K	01.82
O K	72.59
MgK	03.14
AlK	01.46
S K	**1.88**
K K	12.26
CaK	06.85

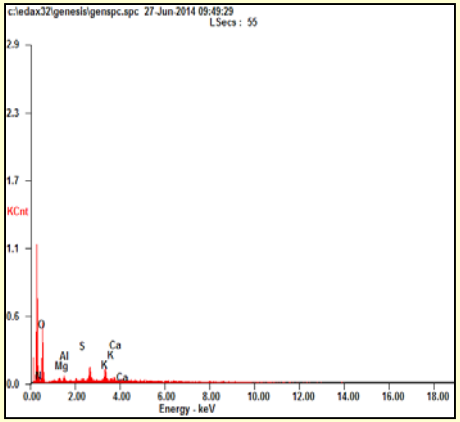
SEM images of Root Nodule







Element	Wt %	At %
C K	50.97	58.56
N K	10.26	10.11
O K	33.96	29.30
MgK	01.28	00.73
S K	**0.83**	**0.36**
K K	02.13	00.75
CaK	00.57	00.20



Element	Wt %	At %
N K	10.81	13.97
O K	64.57	73.09
MgK	02.41	01.80
AlK	03.16	02.12
S K	**2.43**	**1.37**
K K	11.92	05.52
CaK	04.71	02.13

Nano-capsule to Manage Multi-nutrient deficiencies

Nitrogen
Phosphorous
Potassium
Sulfur
Iron
Zinc
Boron
Molybdenum

Nutri-capsule assists achieving balanced crop nutrition and promote pulses productivity

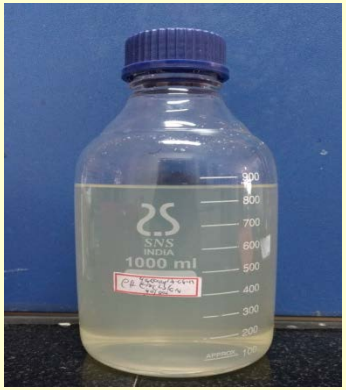
Chitosan Nano-emulsion as Anti-transpirant

Probe Sonicator

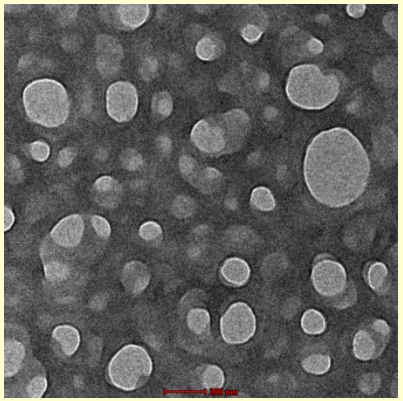
(20 kHz; 30% amplitude, 20 min)

Chitosan Nano-emulsion

(1% chitosan in acetic acid + Tween 80 + Liquid paraffin)

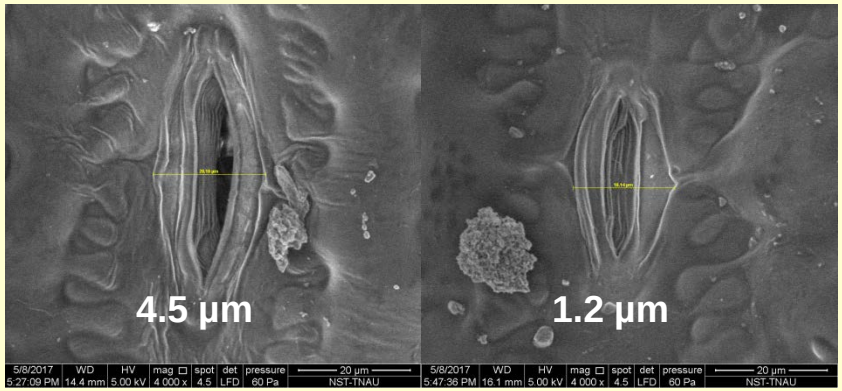


TEM - Micelle



Stomatal Regulation in Maize

Unsprayed **Sprayed**



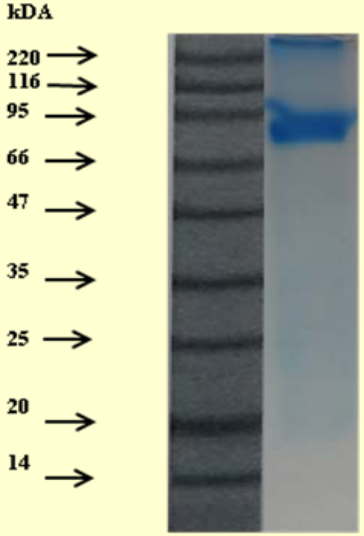
Physiological Responses

Treatments	Trans. rate (mmol $m^{-2}s^{-1}$)	Stomatal conduct. (Gs)	Photosyn. rate (µ mol CO_2 s^{-1})
Unsprayed	20.84	0.71	10.84
Sprayed	18.70	0.56	9.51

(Dr. S. Marimuthu)

Encapsulation of *Pseudomonas fluorescence*

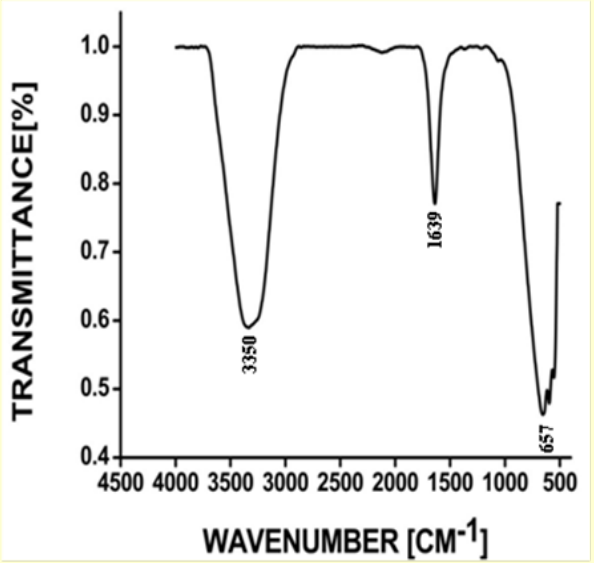
Sericin Protein



GEL : 10% SDS PAGE Gel
Lane 1 : Marker (14-220kDa)
Lane 2 : Purified sericin protein

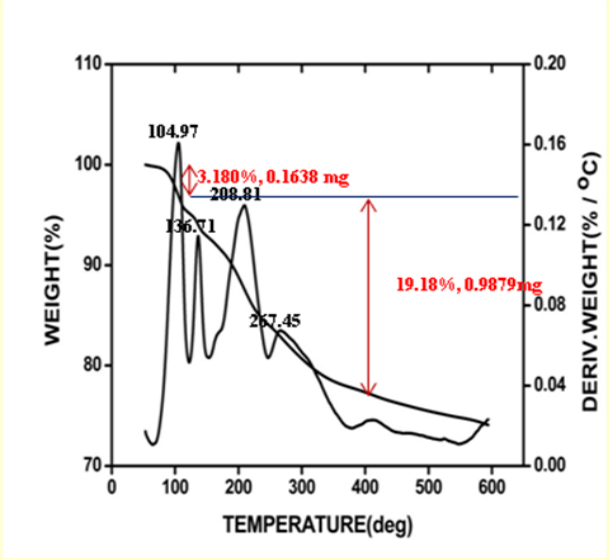
Single band of protein in lane confirms the homogeneity of the purified sericin

FT-IR

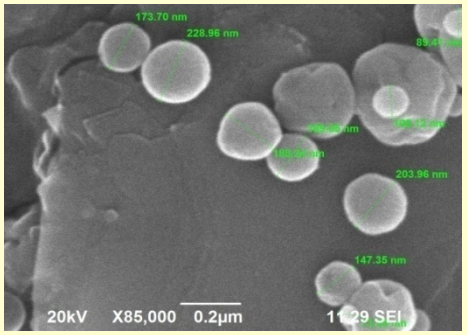


3350 - N–H stretching in resonance with overtone amide II, 1639 - 80% C=O stretching; 10% C–N stretching; 10% N–H bending, 657 – OH bending

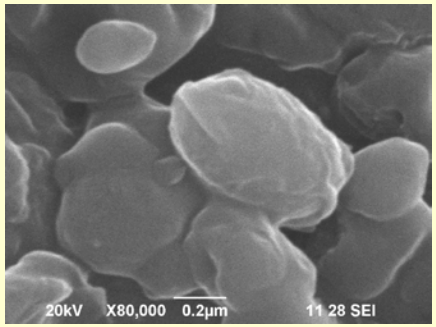
TGA



Sericin



Encapsulated *P. f*

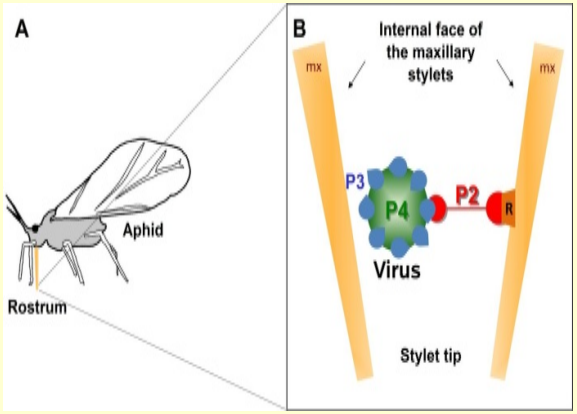


Sericin protein is an excellent encapsulant that protects bioinoculants from high temperature and drought stress conditions

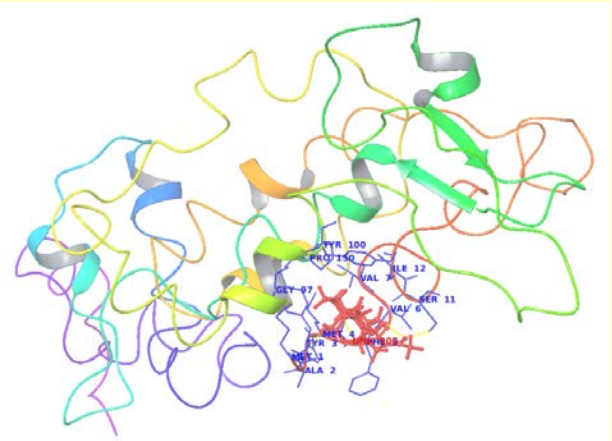
Dr. Pon Sathya Moorthy

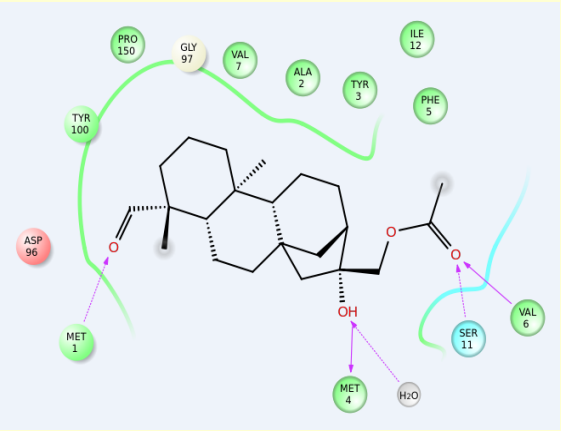
Molecular Modeling of Viral Transmission

Viral Transmission

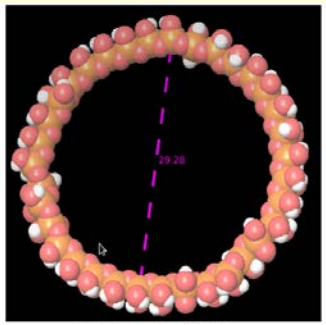


Aphid Viral Transmission Protein bound with annosquamosin

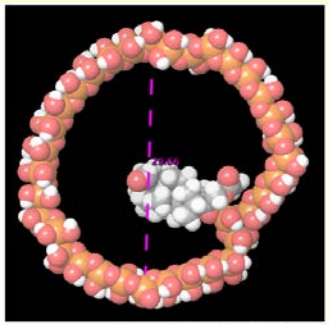




Annosquamosin conjugated in nano-silica

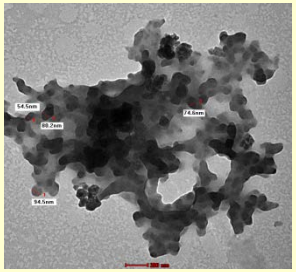


Silica Pore size of 2.928nm



Annasquamosin-A conjugated in the Silica of pore size 2.966nm

Nano-silica as a carrier for annosquamosin



Annosquamosin loaded nano-silica impedes viral transmission from plant to aphid

(Dr. Jeya Sundara Sharmila)

3. Nanotech for Reducing Post-Harvest Losses

Nano-technologies for Fruit Preservation

Nanotech for Fruit Preservation

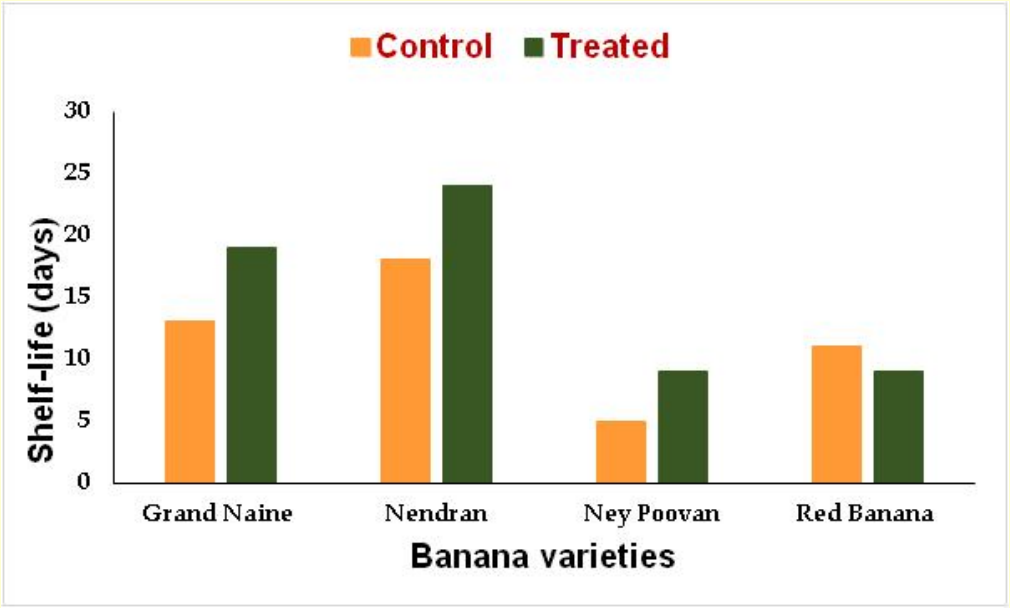
Enhanced Freshness Formulation (EFF)

Extends shelf-life 3 weeks on trees and 3 weeks during storage

Demo on Dip Technology for Fruit Preservation

Nano-emulsion of Hexanal to Extend Shelf-life of Bananas

Nano-Emulsion Treated Fruits Stayed Fresh Longer



Grand Naine

Nendran

Poovan

Red Banana

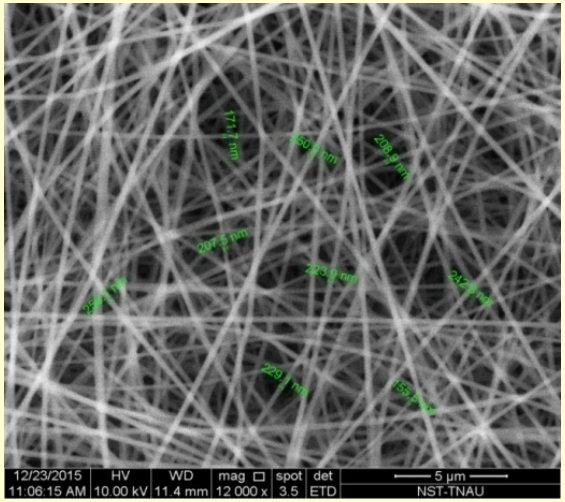
Nano-Stickers

Electrospinning Machine

Aluminum Foil

Nano-Fibre
(PVA 10% + 2.5 ml Hexanal)

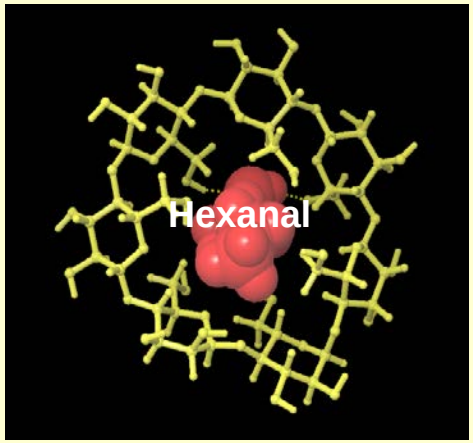
SEM – Nano-Fibre



Nano-Stickers

Packed Fruits

Mangoes Fresh for 12 Days



Control

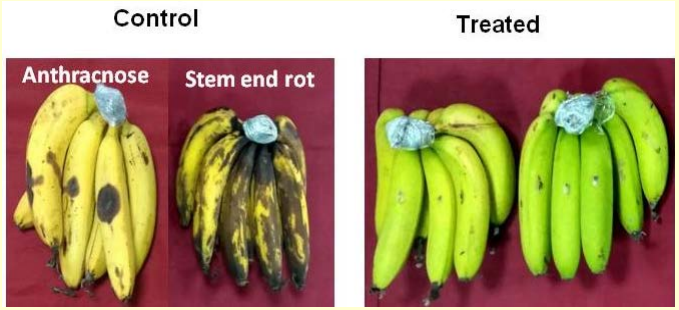
Treated

Benefits

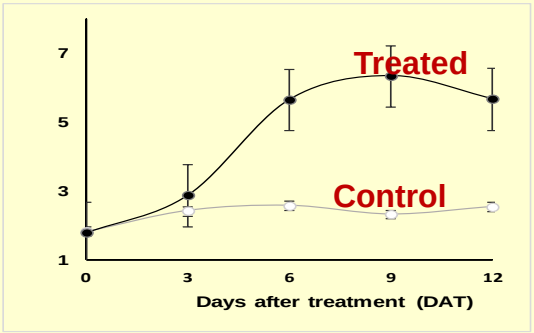
Extended shelf-life
Lucrative income

Hexanal Vapour for Delayed Ripening of Fruits

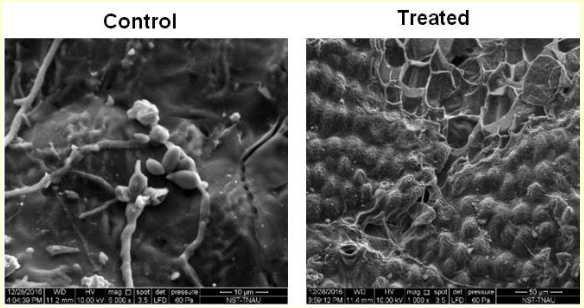
Hexanal Vapour on Fruits



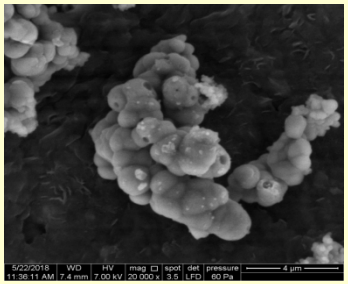
PAL activity in Banana

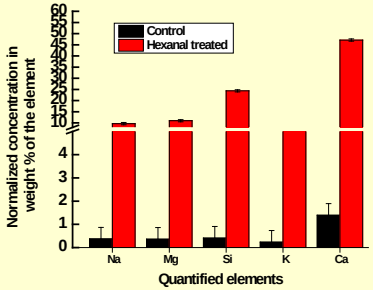


Impedes Infection



Ca Deposition





Fruits	Varieties	Vapour conc. (ppm)	Shelf-life (days)		Disease incidence (%)	
			Control	Treated	Anthracnose	Stem end rot
Banana	GrandNaine	800 ppm 3 hrs	7	14	75.2	80.2
	NeyPoovan		5	12	41.3	21.6
Mango	Alphonso		17	22	46.3	78.7
	Neelum		5	10	86.3	42.1

- **Hexanal vapour at 800 ppm for 3 hrs extended shelf-life of banana by 14 days**
- **Reduction in post-harvest pathogens (*Colletrotrichum gleosporoides & Lasiodiploidia theobromae*)**

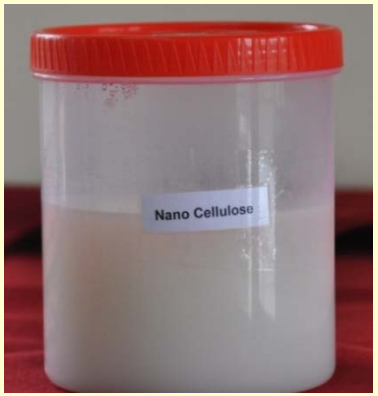
Dr. K.S. Subramanian
Dr. D. Durga Devi

6. Nano-Film to Preserve Tomato

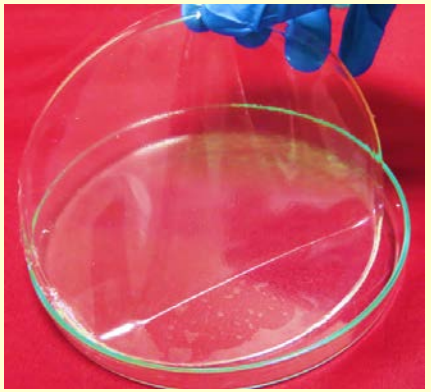
Banana Pseudostem

Extracted Fibre

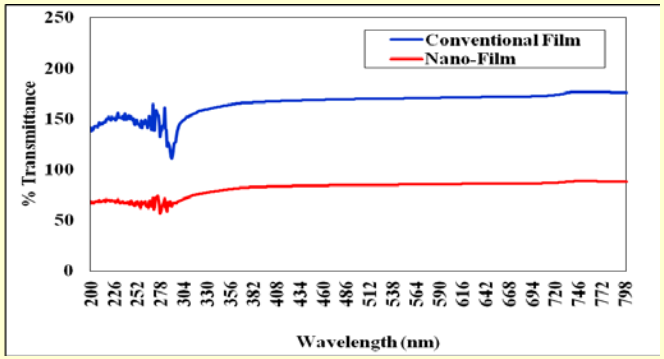
Nano Cellulose



Nano-Film



Relative Performance



Type	ODR (ml/m²/day)	CDR (ml/m²/day)
Cling Film	21770	26503
Nano-Film	498	821

Nano-film for Preservation

Uses

UV resistant

Impedes gaseous exchange

Preserve tomatoes up to 18 days

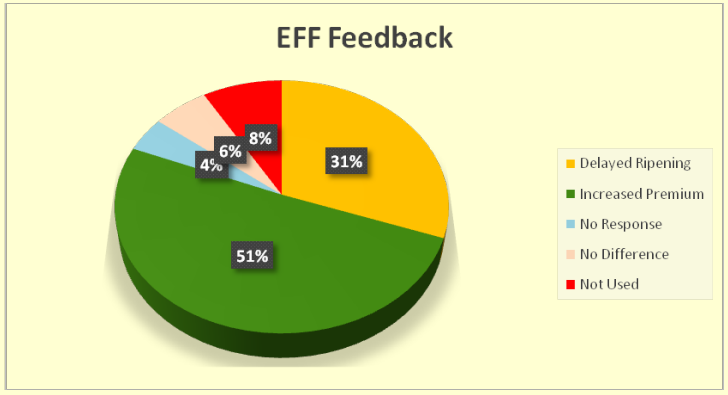
Can be used for cut fruits / vegetables

Biodegradable

Dr. K.S. Subramanian
Dr. G.J. Janavi
Ms. P. Ponni
Ms. Anu Priyadharshini

Feedback

No	Date	Events	Users
1	24.09.2016	Mango workshop at HC&RI, Periyakulam	52
2	28.03.2017	Tamil Nadu Innovative Initiative (TANII) meet at RRS, Paiyur	40
3	21st to 23rd July, 2017	National Banana Festival at AC&RI, Madurai	347
4	2015 – 2018	Department of Nano Science and Technology, TNAU, Coimbatore	68
5	May, 2017	MYRADA distribution in Dharmapuri	519
6	May – June, 2017	MYRADA distribution in Krishnagiri	752
7	July – August, 2017	MYRADA distribution in Theni	500
8	July, 2017	MYRADA distribution in Dindigul	441
9	May – June, 2017	MYRADA distribution in Kolar	612
10	9&10, Feb- 2018	Farmers Day at TNAU	28
11	12th March-2018	Packhouse meet at Krishnagiri	281
		Total	**3640**



Outcome

80% benefitted due to delayed ripening or lucrative price in the market

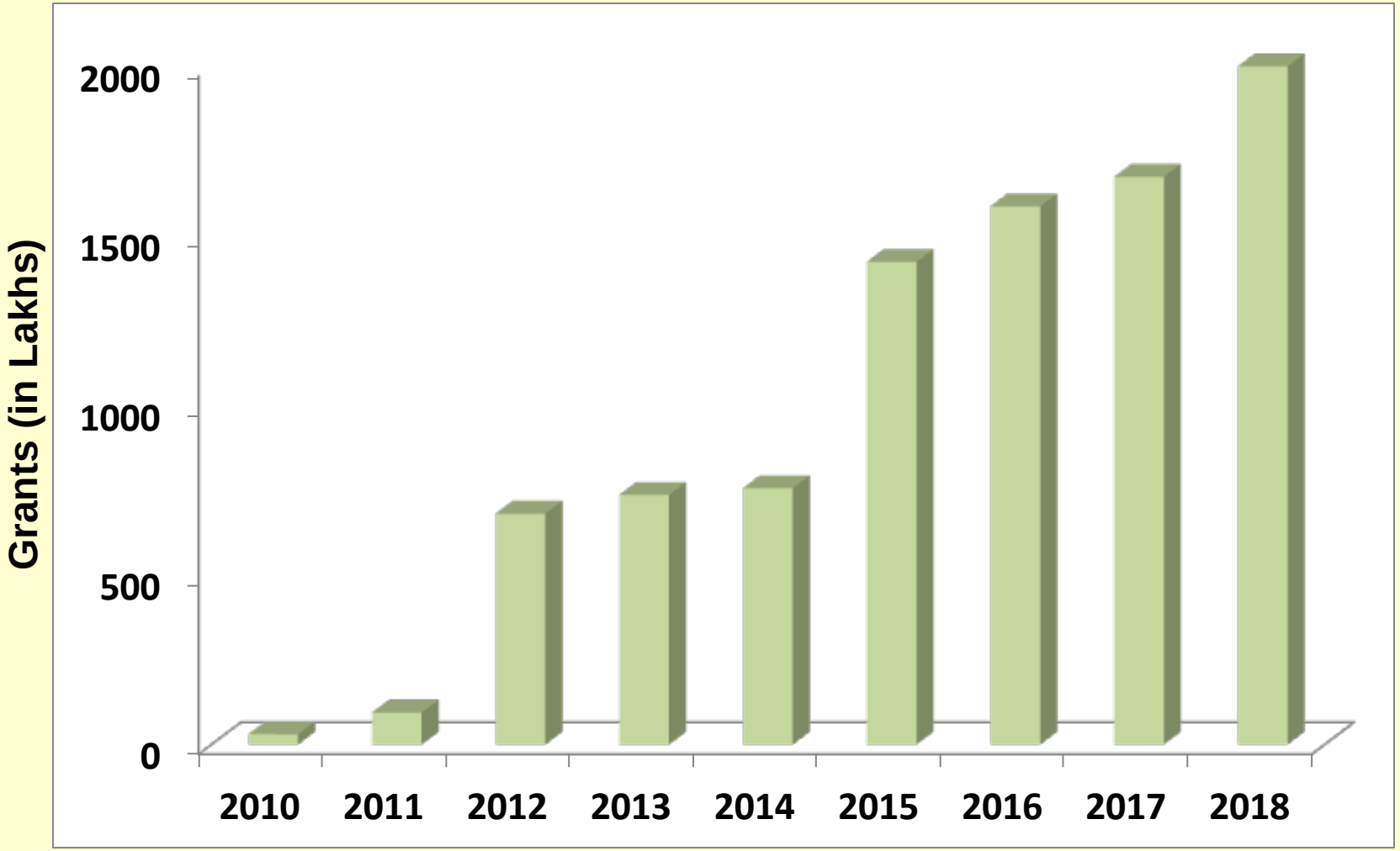
4. Biosafety of Nano-Products

4. Biosafety of Nano-Agri Inputs

(eg. Nano Emulsion as Fruit Preservative)

Trophic Levels	Species Tested	Technique Employed	Inference
Microbes	*Pseudomonas fluorescens* *Bacillus subtilis* *Trichoderma viride, T. harzianum* *Biological activity*	Agar Well / Paper Disk Method Dehydrogenase Assay	No inhibitory effects No ill-effects
Parasitoids	*Trichogramma chilonis* Ishii *T. pretiosum* *T. japonicum*	Contact toxicity method (Treated on the host eggs)	No toxicity till F1 Generation
Predators	*Chrysoperla zastrowi arabica* (Esben - Petersen)	Contact toxicity method (Spray on eggs and grubs of *Chrysoperla*) Food contamination technique (treated *Corcyra* eggs as food)	No mortality detected
Honey Bees	Indian bees - *Aphis cerana indica* F. Italian bees - *Aphis mellifera* L.	Contact toxicity method (treated on mango fruits)	Zero mortality
Earthworms	*Eudrillus eugeniea* (Kinberg)	Contact toxicity method (Sprayed on the soil substrate)	No adverse effect (No weight loss)
Fish	Zebra Fish (*Danio rerio* Hamilton)	Poison Food Technique	No mortality / abnormality
Human Cell lines	*HeLa* - Cervical cancer cells *A549* - Adenocarcinomic human alveolar basal epithelial cells *HepG2* - liver tissue cells	**Lactate dehydrogenase (LDH)** (LDH release into culture medium upon cell death) **MTT assay** (Cellular enzymes reduce tetrazolium dye)	Safer to cell lines (Concentration below 2000ppm is found safe)

Youngest Turned Richest



NABARD Instituted Professor Chair Unit for the Department of Nano Science & Technology

Dr. U.S. Saha, CGM, NABARD Visit to TNAU

Agri-Business Directorate

Nature 559, P23 (2018)

Nature 252, S42 (2017)

COMMENT

EQUALITY Too few people who are LGBTQ go into science, and too many leave p.27

HERITAGE How UNESCO has tried to broker peace through science and culture p.29

EVOLUTION Synthesizing many lines of evidence to trace the spine's start p.31

BIOLOGY Wet labs squeezed by scarce funds and bureaucracy in Italy p.32

ILLUSTRATION BY DAVID PARKINS

A better measure of research from the global south

Funders **Jean Lebel** and **Robert McLean** describe a new tool for judging the value and validity of science that attempts to improve lives.

In India, the world's leading producer of mangoes, up to 40% of the harvested fruit is destroyed in transit before delivery. This costs up to US$1 billion in lost income each year, affecting the lives and livelihoods of millions of farmers, traders and consumers. So researchers from India, Sri Lanka and Canada developed a suite of nanomaterials that can be sprayed onto fruit on the tree, in packaging or in transit, to extend its life. They trapped hydrophobic hexanal molecules (derived from plant waste) in a hydrophilic membrane so that they could be suspended in liquid for application to the fragile fruit.

In Egypt, more than 95% of women have experienced sexual harassment at least once, and most cases go unreported. So, in 2010, researchers at the Youth and Development Consultancy Institute in Cairo developed Harrassmap (https://harassmap.org/en). This online interactive resource enables people to report and map cases of sexual harassment. When it emerged that university campuses were hotspots, Cairo University implemented a policy to combat sexual harassment, the first of its kind in the Middle East. Other universities in Egypt are following suit.

Both projects help to solve pressing societal challenges. The researchers involved ▸

▸ across Southeast Asia — are set to increase in frequency and ferocity as the world's climate changes.

It falls on publicly funded research to take the lead in finding solutions. Since India gained independence from British rule 70 years ago, every prime minister has emphasized the role of science in the country's development. The current incumbent, Narendra Modi, told a meeting of leading Indian science officials in July that science, technology and innovation are the keys to the progress and prosperity of India and that the government aims to apply science to solve the country's problems. As various policy initiatives make clear, India is betting on science to address its pressing challenges in energy, environmental protection, food, water, sanitation, health care and unemployment.

To achieve this, the government is hoping to find more scientists like Koul, who sees his role as an "opportunity to address bigger social as well as scientific challenges".

This is a tall order, and there's an elephant in the room. Government funding for Indian research and development has stagnated at around 0.85% of gross domestic product for more than a decade, compared with at least 3% invested by technologically advanced nations such as Denmark, Japan and Sweden.

Koul is nonetheless optimistic, and has helped to forge a collaboration between IMTECH and Johnson & Johnson, announced in August. They will work in parallel on four new molecules as potential drug targets and explore shorter, safer and more-effective oral treatment regimens for various strains of TB.

BIOPHARMA STRIDES

Koul's collaboration is well placed to take advantage of the success of India's pharmaceutical industry. Building on the solid foundations of the country's expertise in academic chemistry, major pharmaceutical companies have set up factories to make affordable generic antibiotics, vaccines, and diabetes and HIV medicines.

This strength is paying dividends. According to Hyderabad-based Sathguru Management Consultants, India's pharmaceutical industry was worth US$18.8 billion in 2010 and $41.1 billion in 2017, and is expected to expand to an estimated $72.4 billion in 2022. One-fifth of the world's generic drugs are made in India, and around half of this manufacturing is based in Hyderabad.

The production of generics has certainly helped the sector, but many people hope to see the country grow beyond manufacturing. "We now need to be recognized for new drugs that address unmet medical needs," says Kiran Mazumdar-Shaw, managing director of bio-pharmaceutical company Biocon in Bangalore. The firm's growing pipeline of biologics ranges from oral insulin for diabetes to monoclonal antibodies for use in cancer therapy.

"There is incredible potential within India to become a powerhouse driving biopharma innovation in the Asian market," says Vaz Narasimhan, himself a second-generation Indian American and chief executive of Novartis, a pharmaceutical company in Basel. The biopharma industry is increasingly looking for new types of talent, says Narasimhan. He gives the example of data analysts and mathematicians who he says are driving the next wave of medical innovation.

THERE IS INCREDIBLE POTENTIAL WITHIN INDIA TO BECOME A POWERHOUSE.

Narasimhan's confidence in Indian pharmaceutical development is significant. Most pharma companies have been reluctant to take on costly research and development to combat 'poor-man's diseases' such as malaria and TB, says Soumya Swaminathan, one of India's leading experts on TB.

Swaminathan was appointed deputy director-general for programmes at the World Health Organization in October. She has led an effort to consolidate India's fragmented TB research, previously supported by four separate institutions, under one umbrella organization — the India TB Research Consortium. "These diseases are our problem," she says. "And it is pointless expecting Western pharma companies to be interested in them."

When asked, Indian pharmaceutical companies say they are reluctant to take up research in these areas, citing a lack of government funding for early-stage research, and reams of red tape once a product reaches clinical trials.

POLLUTION PAINS

In April, a collaboration between researchers in Germany and Anil Dayakar, an environmental activist in India, reported that Hyderabad's pharmaceutical manufacturing was polluting the region's water system to an "unprecedented" degree, and hurrying the development of drug-resistant forms of bacteria (C. Lübbert *et al. Infection* **45**, 479–491; 2017). The researchers suggested that more regulation was needed to prevent further pollution in the region.

The pharmaceutical industry in India is not the only source of contamination — pollution is common to many of the country's cities, and India's capital, New Delhi, spends its winters wrapped in smog. Krishna Ganesh, director of the Indian Institute of Science Education and Research in Tiruptai, hopes that science can help. "The focus in chemistry is now shifting into areas that involve green and sustainable chemistry," he says. Research topics include non-toxic chemicals, environmentally benign solvents, organic production and renewable materials. "The main aim should be to get rid of toxic chemicals produced in industrial manufacturing," and to prevent gases escaping into the atmosphere, he says.

NANOTECH HOPES

India's strength in chemistry has aided its effort to become a leader in the interdisciplinary field of nanotechnology. It's an especially tempting area of research because there's a deep vein of funding to mine, says Kizhaeral Subramanian, a researcher in the department of nanoscience and technology at Tamil Nadu Agricultural University in Coimbatore. "Global funding for nanotech had increased from $1 billion in 2000 to $2 trillion in 2016," he explains. On top of that, Subramanian says that the country has a strong talent pool to draw from owing to the proliferation of nanotechnology degree programmes across the country.

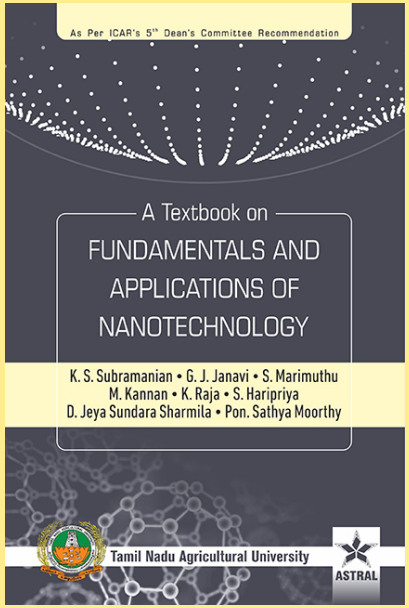
From a developmental perspective, the field is a sensible focus as well. As India's population swells further, the demand for food and clean water is rising. "Nanomaterials can help in water cleansing from bacterial and metal contaminants," says Ganesh, and nanomaterials may also be able to help with crop protection. For example, Tamil Nadu Agricultural University is researching the production of non-toxic herbicides and fertilizers, as well as emulsions and films that improve the shelf life of fruits and vegetables.

ENERGY DARK HOLES

Of India's 1.3 billion citizens, almost 20% still lack electricity. To help combat this, the country has launched an ambitious renewable-energy plan, broadly focused on solar and wind power. Overall, the country hopes to produce 175 gigawatts from renewable energy sources by 2022 — meeting around 20% of the country's predicted electricity demand.

According to Tata Narasinga Rao, associate director of the International Advanced Research Centre for Powder Metallurgy and New Materials in Hyderabad, India enjoys between 250 and 300 clear sunny days each year — ideal for solar technologies. The energy plan is helped by cheap land, a vast pool of talent to draw from and enthusiastic government support and infrastructure, says Rao. In a review published this year, the International Renewable Energy Agency lists India among the six countries — with Brazil, China, Germany, Japan and the United States — that accounted for most of the renewable-energy jobs in 2016.

One research programme, the Solar Energy Research Institute for India and the United States, brings together the Indian Institute of Science in Bangalore and the National Renewable Energy Laboratory in Denver, Colorado,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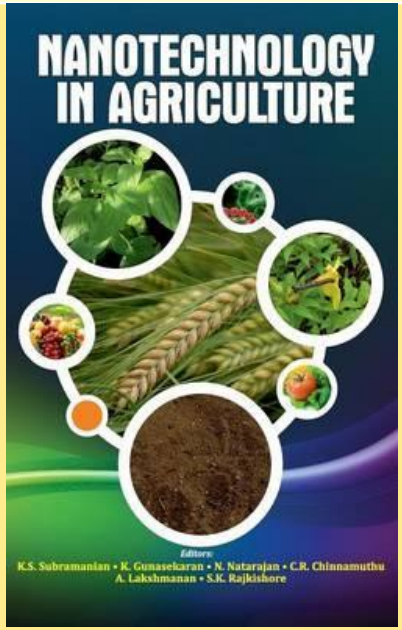
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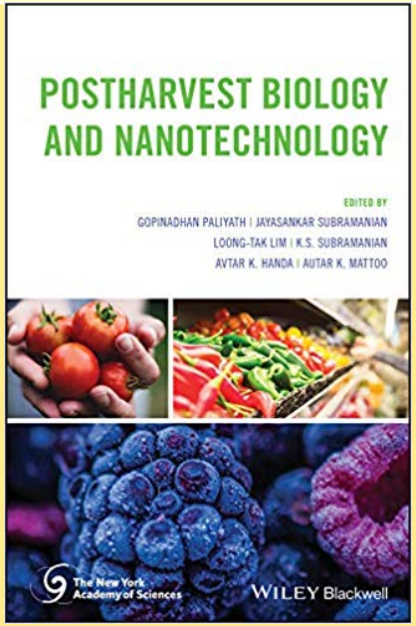
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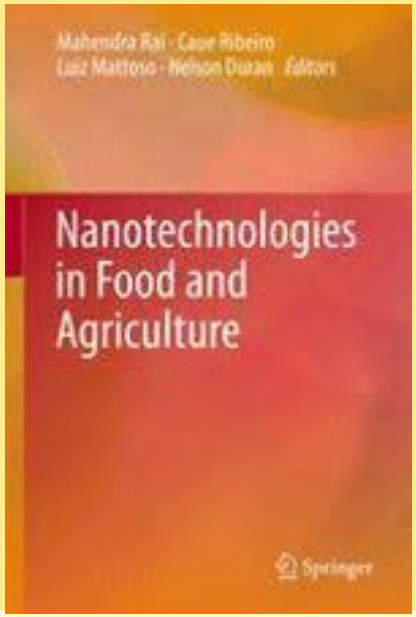
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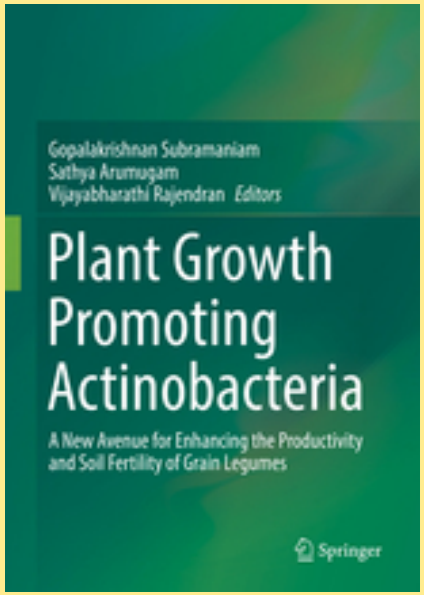
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